# Transformative adaptation as a sustainable response to climate change: insights from large-scale case studies

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## Abstract

Many climate change responses focus on form rather than substance. As a result, they invariably look at the consequences but ignore the drivers of climate change. Since past approaches towards climate change adaptation have had limited success, the most effective and sustainable way to minimize future climate change impacts on humanity is through transformative adaptation (TA). This paper defines and characterizes the conceptual foundations of this term and outlines how TA influences current and future climate change adaptation challenges. This paper reviews the meaning and purpose of transformation in climate change adaptation and, by means of a set of case studies, explains how their commonalities can help define good TA practice. Deploying a range of situations, this study shows how this approach is being implemented in a set of countries, and considers its potential transformative impact, its benefits, and challenges. The results obtained have shown that when implemented with due care, TA can yield long-term benefits to local communities. The paper conclude by listing some measures by which TA may be further deployed as a means of helping communities to meet the future challenges posed by a changing climate.

**Keywords** Transformational adaptation · Climate change · Sustainability · Responses · Livelihoods

## 1 Introduction

The growing need for optimizing climate change adaptation has been discussed for decades, focused, for example, on sustaining livelihoods through the efficient and equitable use of water resources and the development of heat and drought tolerant crops, to enhancing resilience of vulnerable infrastructure, especially along coasts threatened by sea-level rise (Aguiar et al. 2018; Runhaar et al. 2018; Nunn et al. 2020). Today the pace of climate change has accelerated and having multifarious impacts on comparatively complex human societies, signalling the urgent need for adaptation that is effective and sustainable. 'Effective' means that it addresses the issue(s) it is intended to solve (such as flooding, food insecurity); 'sustainable' means that it endures, that it will not cease to be effective within a short time period. These two requirements mean that the best (although not the cheapest or least disruptive) form of adaptation is transformative, one that sustainably reduces vulnerability by understanding, and addressing the root causes.

Given the growing misalignment between adaptation planning and projections of future

climate change, it has been increasingly acknowledged that the most effective and sustainable way to minimize future climate change impacts on humanity is through transformative adaptation (TA). This approach re-defines development by changing the fundamental attributes of socioecological systems in anticipation of climate change impacts (IPCC 2018; Clarke et al. 2018; Saxena et al. 2018; Nunn and McNamara 2019).

The most recent IPCC report on global warming identifies transformative change as a requirement to limit warming to 1.5 °C above pre-industrial levels, integrating it with sustainable development and concerted global action (IPCC 2018). In addition, a number of studies have argued for TA and its importance in effectively and sustainably meeting the challenges of twenty-first century climate change in various contexts (Colloff et al. 2021; Ghahramani and Bowran 2018; Kates et al. 2012; Mechler and Schinko 2016; Pelling et al. 2015; Rippke et al. 2016; Solecki et al. 2017; Nunn and Kumar 2019).

This paper reviews the meaning and purpose of transformation in climate change adaptation and, by means of a set of case studies, explains how their commonalities can help define good TA practice. The contemporary relevance of the paper is that it defines and characterizes the conceptual foundations of the term 'climate change transformation' and outlines how this influences current and future climate change adaptation challenges. The novelty of the paper arises from the fact that it introduces a set of features which are common to TA and discusses the extent to which their commonalities may be a sign of potential success in their implementation. It also deploys a set of indicators, which could provide a foundation for assessing the success of planned/proposed TA.

Later in this paper, we define TA, offer a nuanced understanding of the challenges it presents, outline its implications for current and future adaptation agendas, and provide examples of how TA might best be implemented. Through a series of case studies, we assess potential transformative impacts in a representative range of situations to illustrate its benefits and challenges. We conclude by identifying insights in support of the future deployment of TA as a sustainable means of sustaining human livelihoods in the face of the multifarious challenges posed by a changing climate.

### 1.1 Conceptualizing transformative adaptation

Climate change has already left negative and alarming signs all over the globe, its detrimental impacts typically amplifying inequalities and inequities, including those underlying the sustainability development goals (SDGs), especially poverty, injustice, economic participation, and an uneven access to education (Bel and Teixido 2020; Taconet et al. 2020). In order for humanity to overcome risks from climate change, social and ecological systems need to be reconstituted in ways that will enable vulnerable communities cope effectively and make optimal use of available opportunities to adapt (Dupuis and Biesbroek 2013; Leal Filho et al. 2019). Sustainable adaptation is the end goal when climate change is the principal issue of concern. The spectrum of adaptation ranges from short-term coping strategies, such as strengthening infrastructure and relocating people occupying exposed

places to systemic changes that imply paradigm shifts, i.e. instead of fighting the threat trying to redesign the conditions to live with it. For example, by means of setting up ad hoc or permanent infrastructure to withstand water flows, natural flood risk management approaches that use catchments to store excess water may be preferred to ones that involve fighting the floods (Bracken et al. 2016; Termeer et al. 2017).

For the purposes of a better understanding of the diversity of TA, building on the groundbreaking work of Kates et al. (2012) and Huq (2017), the authors of this paper framed the concept of TA by means of three criteria:

i. adopted at much larger scale or intensity;
ii. truly new to a particular region or resources system;
iii. transforming places and/or shifting locations.

Although this is outside the scope of this paper, we note that TA can sometimes include all these three groups at the same time.

TA is defined as a fundamental and systemic change for sustained equitable growth which can secure sustainable societal development while ensuring social equity, optimizing financial efforts to strengthen resilience on various scales, and minimizing the risk to local livelihoods amplified by accelerating climate change (World Resources Institute 2019; Wallace and Silander 2018). Public policies that pursue mitigation and adaptation goals alike may facilitate the uptake of TA and foster public understanding of interrelatedness (Brink and Wamsler 2019; Gillard et al. 2016); in a developing world context, the empowerment of local communities to grasp the change and incorporate it within their own development agendas is a prerequisite for successful TA (McNamara et al. 2020).

The concept of TA also builds from the scholarly literature that unpacks the interlinkages between climate change adaptation and development, with the aim of both explaining mutual effects (Boyd et al. 2009) but also demonstrating the key role of interdisciplinary approaches (Schipper 2007, Ayers and Huq 2009). In this regard, a study by McGray et al. (2007) screened more than 100 projects considered to be climate change adaptation initiatives (undertaken in the context of developing countries), finding that the beneficial outcomes of the projects made little difference to what can be considered as good development (Klein 2010). McGray et al. (2007) identify a continuum of actions that can be undertaken in order to address climate change impacts and promote long-lasting adaptation. These range from pure development actions, with usually no intentions to tackle climate change adaptation, to purposely designed adaptation efforts. When the first set of actions, aimed at addressing vulnerabilities, has a positive effect on adaptation, this is known as the 'no-regret, win–win' option (Kelly and Adger 2000: 333). On the other hand, the actions targeted to specific climate change impacts might not have any effect on development, unless they are effective at tackling climate change adaptation. In between 'lies a broad spectrum of activities with gradations of emphasis on vulnerability and impacts' (Bapna and McGray 2008: 2). Based on this understanding, our proposed measurement of TA takes the shape of a scale, ranging from low to high TA levels.

### 1.2 The challenges of transformative adaptation

TA presents a number of challenges for decision-makers, researchers as well as practitioners, not the least of which is the demand for capacities like 'leadership for transformation', the capacity for systemic inquiry, and for learning from practice (Lonsdale et al. 2015; Clarke et al.

2018; Lavorel et al. 2019). Initiating effective and most importantly sustainable adaptation requires a different conceptualization of TA; in line with the pathway discourse, adaptation may be considered as an element of possible pathways that are characterized by interacting global changes and societal responses which, in turn, may be shaped by historical determinism and certain path dependencies (Wise et al. 2014; Runhaar et al. 2018; Nunn et al. 2021a, b).

Owen (2020) defines effective adaptation as including one or more of the following: reducing risk and vulnerability, developing resilient social systems, improving the environment, increasing economic resources, and enhancing governance and institutions. TA thus requires key actors to extend their modelling expertise to address the potential for transforming current limitations of local adaptation (Shi 2019; Singh et al. 2019). Furthermore, to support TA and related decision-making, novel approaches need to be developed to properly assess, evaluate, and adaptively manage the likely compromise between adapting to major biophysical changes and maintaining the properties of existing socio-ecological systems (Colloff et al. 2021; Leal Filho et al. 2017).

The challenges of applying this approach and convincing key stakeholders to adopt it (rather than cheaper, easier-to-implement shorter-term adaptive solutions) are related not just to the difficulties of inducing a fundamental systemic change but also to uncertainties about the associated risk decision-makers need to take into account and society may have to bear. The application of TA also involves addressing the scope and just distribution of benefits, comparatively high financial and social costs of transformational actions for society, and the understandable public resistance against institutional and behavioural actions that would change existing resource systems and policies (Kates et al. 2012; Saxena et al. 2018).

As demonstrated in recent studies of African cities (Revi et al. 2014; Leal Filho et al. 2018; Nhamo et al. 2021), urban centres proposing to embrace TA must address excess greenhouse gas emissions, the root causes of poverty and associated failures of sustainable development, and the competence, capacity, and willingness of local authorities to adapt effectively and sustainably. Rural areas on the other hand, facing different sets of challenges, usually regard TA as a process leading to changes such as a reduction in vulnerability or increase in resilience capacity at community level. The success of such TA would seem to depend on (rural) community autonomy and commitment to drive change, as well as the foregrounding of familiar worldviews and knowledges (McNamara et al. 2020; Furmankiewicz et al. 2021).

TA can also challenge the specific social structures and processes related to economic predominance, for instance by enabling vulnerable groups and the poor to overcome systematic inequity and marginalization through being involved in decision-making (Warner and Kuzdas 2017). There have recently been calls for developing countries to become less dependent on richer ones for climate change adaptation, to 'own' adaptation and to localize it, given that future levels of assistance are likely to decline sharply as the costs of domestic adaptation in donor countries rise (Korovulavula et al. 2019; Nunn and Kumar 2019; Barbier and Burgess 2020).

### 1.3 The benefits of transformative adaptation

Given that it builds on preventing maladaptation and also encompasses incremental adaptation, TA is increasingly being proposed as a sustainable approach to managing unavoidable twenty-first century climate change risks (Termeer et al. 2017; Colloff et al. 2021). TA also has the potential to reconfigure risk profiles of various parts of the world, from countries to communities, in ways that might be expected to sustain their inhabitants' livelihoods (Wilson et al. 2020).

In some instances and contexts, the magnitude of vulnerabilities and risks may exceed normal conditions, overwhelming resilient resource systems; examples are recent increases in the severity of tropical cyclones (hurricanes) that have seen winds of unprecedented strength damage human systems unaccustomed to these (Eppinga and Pucko 2018; Sattler 2017; Terry and Lau 2018; Walsh et al. 2016). Given that they may become more usual in the future, such uncommon (yet increasingly common) situations require transformational rather than incremental adaptations or even a naïve belief in restoring systems to their pre-impact states. Although it could be considered in its infancy, evidence of the benefits and potential benefits of transformational adaptation are beginning to emerge.

For instance, salinity intrusion attributable to sea-level rise has been identified as a major climate change risk for millions of residents in Bangladesh's low lying coastal-deltaic zones, as well as some low-lying Small Island Developing States (SIDS) (Gingerich et al. 2017; Dasgupta et al. 2018). Pregnant women are particularly vulnerable to the effects of saline water consumption and the provision of clean water has been proposed as an ideal incremental adaptation strategy. Yet in a transformative scenario, the vulnerable female population could become change agents for the entire country by prioritizing women's education in a radical departure from existing practice. Large-scale investment in quality female education would equip the vulnerable female population with the requisite skills to make them employable in less vulnerable places away from the hazardous coastal region (Tanjeela and Rutherford 2018). Similar initiatives have been undertaken in many low-lying (atoll) island nations whereby inhabitants, recognizing the future likelihood of resettlement in other countries, have been encouraged to acquire qualifications to increase their future employability (Hermann and Kempf 2017); such an idea underpinned the 'Migration with Dignity' policy of former Kiribati president, Anote Tong. In the long term, it is anticipated that the effects of such investments, including generating educational and employment opportunities in less vulnerable places, will encourage voluntary relocation away from vulnerable communities and greater agency, thereby boosting climate change resilience via autonomous transformational adaptation (Yoshioka et al. 2019; Rivero-Villar 2021).

Place attachment is one of the relevant considerations in assessing the benefits of TA (Clarke et al. 2018). Many rural communities, especially in developing-country contexts where land ownership is communal and inherited rather than individual and purchasable, have ties to land that they consider to be immutable, meaning that the idea of relocation elsewhere is 'barely conceivable' (Kempf 2012:250). Yet it is also clear that the land occupied by many such communities, especially along low flood-prone coastal fringes, will become uninhabitable within a decade or so as a result of rising sea level. Incremental solutions (like seawall construction) are popular because they are comparatively cheap and appear, initially at least, reassuring (Nunn et al. 2021a, b). But the durability of such incremental solutions in such places is often quite short-lived, 'the coasts of the Pacific Islands are littered with the remains of collapsed and ineffective seawalls' (Dean et al. 2016:74), while on Indian Ocean islands, 'broken seawalls and groynes and useless structures … are still lying on beaches, spoiling the scenery and disturbing human activities' (Duvat 2009:155). These situations show the failure of incremental adaptation and point towards a need for TA, in this case the relocation of the exposed and vulnerable communities to less-vulnerable locations. This is a challenging issue in many developing-country contexts where people have cultural-historical ties to places on which their livelihoods also depend (Albert et al. 2018; Piggott-McKellar et al 2019b). It is important to note that people with less place attachment have a higher likelihood of adopting TA requiring migration from high-risk areas (Marshall et al. 2014).

Overcoming a reluctance to undertake TA has been helped by providing livelihoods for people in the new location, as shown by the provision of fishponds for the community of Vunidogoloa (Fiji) that was relocated several kilometres inland (Piggott-McKellar et al. 2019a, 2019b). In addition, in many smaller-island contexts, it is possible to move communities to less-vulnerable locations yet still allow them to access familiar places for food acquisition; Fiji examples come from the relocated community on Yadua Island (Martin et al. 2018) that is just 500 m from its former location and that at Narikoso on Ono Island which has recently moved about 200 m upslope (Barnett and McMichael 2018). To optimize their chances of sustained success, relocation processes should include community consultation, guaranteeing free and informed consent of the relocated population (McAdam and Ferris 2015), something that should also apply to community adaptation per se in such situations (McNamara et al. 2020; Westoby et al. 2019).

In many contexts, competition for land from recent developments and infrastructure for places to which particular groups of people are historically and culturally attached has highlighted the importance of place attachment. In addition, transforming places involuntarily because of extreme weather events or an absence of community involvement in decision-making processes have commonly derailed sustainable development of the affected people; examples of the latter include the effects of protected areas on their indigenous inhabitants (Boillat et al. 2018) and mining (Dupuis and Biesbroeck 2013). Transformation of individual understandings or knowledge may prove beneficial for proactive adaptation, but individuals who express a strong attachment to place may continue to adopt contradictory positions, something illustrated by the possibility of 'voluntary immobility' as a future response to climate-driven sea-level rise in the atoll nation of Tuvalu (Farbotko 2019). If affected populations become partners in adaptation planning rather than its uncomplaining recipients, this allows them to actively cooperate in the best possible solutions; strong calls have been made recently for those accustomed to design, fund and implement adaptation planning for supposedly helpless communities to meaningfully involve them (McNamara et al. 2020).

Another major advantage of TA in many situations is the large scale of deployment, bringing benefits to a greater number of people than is usual in such interventions. For instance, the natural regeneration/regreening of the Sahel by farmers to address drought-induced farming problems is very popular in the region; about five million hectares of climate change resilient green belt have been created (Goffner et al. 2019). TA also supports anticipatory initiatives which entail planning for future risks long before they occur. The UK's Thames Estuary 2100 Plan envisions transformative responses to sea-level rise involving the construction of an enhanced barrier at a separate place in addition to avoiding construction in flood-prone areas after 2060. Such visionary and well-thought-out long-term plans enable local authorities and residents to cope well with future risk scenarios, thereby enhancing urban sustainability (Leal Filho et al. 2019).

Novelty and innovation constitute a set of benefits that is distinct from transformative approaches. TA supports innovative concepts, which could be entirely novel or an integrated combination of existing concepts and resources provided by various collaborators to be deployed in new locations. For example, crop insurance against weather loss which hitherto existed in developed countries (Di Falco et al. 2014) is now being implemented in developing countries as well (Cole and Xiong 2017; Reyes et al. 2017)). Similarly, the Netherlands' transformational adaptation program is a long-term novel initiative combining aspects of all three types of transformational adaptation. The large-scale innovative project includes a planning horizon exceeding two centuries. This is projected to enhance the overall flood protection level of the Rhine and Meuse rivers tenfold and generate a minimum sum of about 1 billion Euros every year over a protracted period (Kates et al. 2012).

In terms of sectoral benefits, agriculture is undoubtedly a major beneficiary of TA as a means of sustainable response to climate change. Changing sustainability and productivity of systems affected by climate change have become a priority (Marshall et al. 2016; Ghahramani and Bowran 2018). Based on UN projections, 6.5 billion people will be living in cities by 2050 and global food security is endangered by ongoing urbanization involving out-migration from traditional agricultural centres. In the USA alone, the percentage of the population involved in productive farming is < 3; 60% of these farmers are above the age of 60 (Harper 2016). Transformative initiatives to adaptation in the agricultural sector are essential to strengthen global food security (Bene et al. 2020) and are also required to prevent maladaptation and minimize risks arising from conflict (Froese and Schilling 2019) as well as aligning better with the capacities of the natural world within a changing climate (Runhaar 2017).

Current adaptation practices in the agriculture sector offer relatively few incremental adjustments to existing systems. Several studies (e.g. Ghahramani and Moore 2016; Lesk et al. 2016; Vermeulen et al. 2013) show that incremental adaptation strategies may adequately address climate change impacts, requiring that ways are found to compensate for losses of agricultural production (Ghahramani and Moore 2015). Yet the rise in extreme climate and weather events is beginning to neutralize the gains of such comparatively minor adjustments (Carter et al. 2018), signalling the growing need for transformative approaches. Further evidence from isolated rural communities in Fiji show that the integration of traditional knowledge and cultural practices into climate change adaptation is a further key element to promote transformational changes (Moncada and Bambrick 2019). The scale, novelty, and holistic measures provided by TA are essential to manage these impacts and minimize risks, enhance food security, and preserve livelihoods of vulnerable communities.

Transformative approaches may also vary, depending on place and condition. For instance, TA to climate change in Africa is imperative. Not only must it be at a larger scale with new innovations, ambitious enough to take political steps that may not be easy or quick, but it needs to be integrated fully into the overarching issues that will truly transform Africa's agriculture (Grist 2014; Leal Filho et al. 2022). Fostering changes in conventional agriculture by deploying heat- and drought-tolerant crops, for example, may help to reduce poverty and prevent malnutrition (Leal Filho et al. 2019) as may policies intended to increase numbers of medium-size farms in drier parts of the continent (Jayne et al. 2019).

A spike in demand for new (and demonstrably effective) adaptation initiatives to protect communities is anticipated as climate change impacts and threats increase in frequency and magnitude (Colloff et al. 2021).

## 2 Materials and methods

The methodology pursued in this paper can be described as purposive sampling of case studies via an extensive climate change research and information network. For data collection, the researchers applied a convenience sampling technique which resulted in ten potentially transformative case studies from six countries. The selected case studies had to comply with the framing of TA (see Sect. 1.1) in order to qualify for further analysis. In a next step, the case studies were assessed against this framework as well as according to their typical dimension(s) of adaptation, that is being responsive, anticipatory, technological, behavioural, collective, or autonomous. As shown in Table 1, the results illustrate that

90% of the ten case studies selected can be classified as being truly new to a particular region or resource system. Prevailing types of adaptation included responsive (9), technological (8), or collective (7,5) dimensions.

Transformational adaptations imply large-scale interventions based on flexibility instead of rigid ways to fix the existing situation. A series of smaller steps comprise the intervention at stake, attempting to adjust human demands in relation to problems due to climate and affected land changes. Nevertheless, since transformational changes need responses, it is quite common to detect development actions that fail to address stimuli or to identify the source of vulnerability, as a result of which the outcome final change is superficial (Warner et al. 2019). TA will gradually be significant to successfully mitigate the impacts of climate change and other global burdens that pressure social-ecological systems. New evaluation and managerial techniques are necessary to enable TA, including maintaining desired levels of social-ecological systems and adapting to relevant biophysical changes (Colloff et al. 2021).

To explain the potentially transformative impact of the assessed cases, the authors performed an analysis of the key observations. For this analysis, the authors commenced with established monitoring and evaluation (M&E) procedures. Grounded in a theory of change, a set of indicators was developed that served to deeper assess the transformative scope of the respective case studies, evaluating to what extent the outputs and outcomes of each case study might explain the observed transformative change. As defined in the relevant literature, necessary preconditions for transformative change, hereafter termed 'indicators', are presented in Table 2. The indicators used were selected due to their special features, as follows:

a. Innovation/novelty
b. Evidence of effectiveness as proven measures
c. Sustainability in terms of not depending on foreign donors
d. Political interest to implement them
e. Community involvement in the implementation
f. The collaboration of various stakeholders sharing tasks
g. Possibilities of replicability

For each indicator, the case studies were classified along the seven in-depth indicators, following three qualitative categories — low, moderate, high — according to their characteristic value. The category 'not applicable' (NA) was used when insufficient information was available in the case studies to allow classification. The next section presents the results of this analysis and explores the case studies by presenting their scope and the rationale behind their classification.

## 3 Results and discussion

### 3.1 Results

The assessed cases show some commonalities that may serve to characterize them as good practice example for TA. From the classification and characterization illustrated by Table 1, it can be observed that all but one case study meets the criteria of at least two out of the three defined classes used to frame the transformative effect. The most often observed class refers to the inherent novelty of the proposed solution for the respective region or resource

**Table 1** Classification and characterization overview of all case studies

| | Case studies locality | Classes | | | Characterization | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Larger scale/more intense | New to a region or resource system | Transforms places and shift locations | Responsive | Anticipatory | Technological | Behavioural | Collective | Autonomous |
| 1 | Turkey | (x) | x | x | x | | x | | x | |
| 2 | Migori county (Kenya) | | x | | x | | x | | x | |
| 3 | Galicia, Extrema-dura and Cataluña in Spain | Cannot be determined, yet | | | x | | x | | x | |
| 4 | Bangladesh | Xx | x | x | x | | x | | x | |
| 5 | Bangladesh | x | x | x | x | | | x | (x) | |
| 6 | Bangladeshx | x | x | | | x | | x | x | |
| 7 | Bangladesh | x | x | | x | | x | | x | |
| 8 | Kenya | | x | x | x | | x | | x | |
| 9 | Rajasthan, India | | | x | | x | | x | | x |
| 10 | Honduras, Central America | | x | x | x | | x | x | | x |
| | *Score* | *4,5* | *8* | *6* | *8* | *2* | *7* | *4* | *7,5* | *2* |

**Table 2** Selected indicators used for evaluation

| No | Indicator | Description | Source (based on) |
|---|---|---|---|
| 1 | Innovation | Activities support innovation and test new approaches | Brooks et al. (2014) |
| 2 | Evidence of effectiveness | Ideas and lessons are extensively shared | |
| 3 | Sustainability | Activities do not rely on continuous funding | |
| 4 | Political will and local ownership | Activities foster political will to act on climate change | |
| 5 | Community-based adaptation (CBA) | Interventions based on consultation with the affected and potentially collaborating communities<br>Activities identify the most pressing and impacting challenges<br>Communities might have community-based solutions to offer, but lacking the means to implement them<br>Place attachment contributes to ownership of TA interventions by communities | Dodman and Mitlin (2013)<br>Ensor and Berger (2009)<br>Schipper et al. (2014)<br>Ayers and Forsyth (2009) |
| 6 | Multi-stakeholder collaboration and efficient division of tasks | Research-based intervention designs coupled with active community co-management involvement<br>Countries and communities have the capacities and capabilities necessary to bring the change about and act on climate change | Sherman and Ford (2014)<br>Brooks et al. (2014) |
| 7 | Influence/spillover effect and replicability | Support existing practices or create new ones adapted to the communities' intervention, and when businesses are involved, their buy-in is required<br>Effective and synergistic use of urban interventions can solve existing urban problems and help achieve climate change adaptation, besides promoting incentives for others to act and having the potential to be replicated | Biagini and Miller (2013), Ojea (2015)<br>Dulal (2017), Brook (2014), and Reid and Schipper (2014) |

system. This latter finding is backed by the findings summarized in Table 3 in which a set of seven indicators — and the resulting key benefits derived from them — are listed.

In Table 1, the first of the seven indicators directly refers to novel, innovation-related aspects. A number of case studies have been awarded a high or medium score, for example, the first three from Turkey, Kenya, and Spain which refer to new configurations of resource systems. The second one addresses dimensions of effectiveness which could be identified in the Indian, Turkish, and Bangladesh cases. The third, i.e. sustainability, dimension was present in all cases except for Kenya, Spain, and one Bangladesh case. Finally, the cases in Kenya and Bangladesh showed distinctive traits of community-based adaptation and multi-stakeholder collaboration.

A more striking observation relates to the characteristic dimensions explored (see Table 1). From a climate change lens, responsive, technological, and collective adaptive traits were observed — these characteristics stood out with most of the cases assessed. The first trait (responsiveness) is somewhat surprising as, in theory, TA anticipates future risks and uncertainties (Mustelin and Handmer 2013). The fundamental, systemic transformative nature of adaptive action might therefore rather be triggered by a severe problem or a disastrous event rather than a projected future that requires a somewhat abstract need for change.

Summarized in Table 4, the case study from Turkey involves six companies from different sectors which implemented resource efficiency and sustainable production applications that resulted in water, materials and electricity reduction, and a considerable amount of savings that improved productivity and long-term profitability. In Migoru county, Kenya, a participatory multi-stakeholder process was promoted to manage snow-harvesting, which combined with efficient water-use practices and financing mechanism, allowed stakeholders to start adapting to prolonged periods of droughts and water scarcity. Different draught resistant crops were planted in a high value timber walnut farm plantation in the regions of Galicia and Cataluna in Spain, allowing the farmers to enjoying higher yields and the long-term survival of crops.

Ecosystem and community-based adaptation projects in Bangladesh that afforested Mangrove forests supported coastal settlements to adapt to the slow onset of sea-level rise and to the increased incidence of storm surges, including providing some income generation activities from the produce of the trees. The implementation of hydroponic farming systems in Bangladesh allowed coastal settlements to rely on a less resources intense system to produce food, adapting to current and future storms and extreme events that would have halted food production. A further project in Bangladesh promoted integrated farming methods to allow farmers to adopt alternative agriculture practice for producing rice, shrimp/fish, and vegetables/fruits in the same parcel of land in the same time, maintaining good quality water levels almost all year-round.

Communities in South-East Kenya were supported to construct sand dams to capture and store rainwater, providing a safe all year-round water supply for communities. Further farming techniques (terracing, establishing tree nurseries, and planting drought tolerant crop varieties) combined with a reliable and safe water source from the sand dams enabled communities to become food and water secure, possibly also addressing health and socio-economic concerns. In Rajasthan, India, the agriculture sector enjoyed the promotion of an indigenous variety of wheat, kharchia, which seems to resist to higher temperatures, increase in salinity, and decrease in soil organic matter, supporting farmers that are frequently facing crop failure, with serious consequences on food security. Water saving and management technologies have enabled farmers to increase water and food security, including reducing conflicts between farmers for water use.

**Table 3** Key findings of the in-depth evaluations

| Country and title of case study | (Key) Benefits derived Based on:<br>1. Innovation;<br>2. Evidence of effectiveness<br>3. Sustainability<br>4. Political will and local ownership<br>5. Community-based adaptation<br>6. Multi-stakeholder collaboration, efficient division of tasks<br>7. Influence/spill-over effect and replicability: |
|---|---|
| Turkey<br>Adaptation to climate change in industry: improving resource efficiency through sustainable production applications | 1.high, because this study was the first ever activity in Turkey which was devoted to the adaptation to climate change in the private sector<br>2. high, due to paper publication<br>3.medium, since the project started with collaboration with a research institution<br>4. NA<br>5. NA<br>6.medium, due to partnership only between the research institution and the manufacturing companies<br>7.high, since this study served as a building block in the country, may assist other countries as well in integrating climate change adaptation and mitigation approach in industry |
| Kenya<br>Mitigating climate change induced drought in harvesting and water use efficiencies: a case of agriculture in Migori County | 1.high, considering the development of an idea to overcome a new challenge for the region<br>2. NA<br>3. NA<br>4. NA<br>5.medium, farmers participated in the process of developing the solution, but there is no evidence of further community participation<br>6.high, bringing together farmers, businesses, government and civil society organizations<br>7.high, since the approach was considering important to involve all stakeholders and then be used to overcome other development challenges |
| Spain<br>Agroforestry systems for cereal production as an adaptation and mitigation strategy to climate change in the Iberian Peninsula | 1.high, due to exploration of symbiotic outcomes from different combinations of cereals, varieties and trees<br>2. NA<br>3. NA<br>4. NA<br>5. NA<br>6.medium, collaboration between a research institution and a timber farm business<br>7. NA |
| Bangladesh<br>Community based mangrove afforestation and restoration project in South-central Coast | 1.medium, by providing new forms of income- generating activities to the residents<br>2.high, the community has been trained in the benefits of the use of mangroves and plant density to address core challenges in the area related to the environment and sustainability<br>3.medium, the case relied on active collaboration between the government and the local community<br>4. high, due to government involvement<br>5.high, as the title suggests through the implementing of a participatory CBA<br>6. high, between costal residents and government<br>7. medium, evidence of co-benefits in coastal areas |

**Table 3** (continued)

| Country and title of case study | (Key) Benefits derived Based on:<br>1. Innovation;<br>2. Evidence of effectiveness<br>3. Sustainability<br>4. Political will and local ownership<br>5. Community-based adaptation<br>6. Multi-stakeholder collaboration, efficient division of tasks<br>7. Influence/spill-over effect and replicability: |
|---|---|
| Bangladesh<br>Community based Sundarbans' mangrove protection and conservation project in South-western coast | 1.medium, introducing a conservation-linked value chain approach to provide more sustainability to the resources whilst also offering new forms of income generation for the population<br>2.low, the community was actively involved at consultation stage, whilst implementation was largely government led<br>3.high, since the local population now knows how to plant the dykes and their surroundings with trees in order to stabilize them and prevent air and water induced erosion and breaching from surges<br>4. high, due to government involvement<br>5.high, as the title suggests through the implementing of a CBA strategy<br>6. high, involving local community and government agency<br>7.medium, this initiative created new income opportunities for the local population and also protected the Sundarbans mangrove ecosystem |
| Bangladesh<br>Community based wetland restoration and hydroponic agriculture in south-western | 1.medium, the intervention led to the setting up of hydroponic systems through transfer of sills<br>2. NA<br>3. NA<br>4. medium, due to participation of government agencies<br>5.high, local communities were extensively consulted to identify their problems, and priorities to ameliorate the problem<br>6.high, adaptation measures have been employed by government agencies, local NGOs, and the community people to restore the wetland characteristics<br>7.high, the CBA delivered a range of social-ecological benefits to local people including micro-irrigation, fish culture, soil binding, nutrient recycling, flood, and erosion control which help building community resilience against water related disasters. Community based hydroponic farming or floating garden agriculture has also been introduced |
| Bangladesh<br>Coast community based integrated farming for rice, fish and fruits | 1.medium, changes in the agricultural production through integrated farming produced more diverse crops from the same parcel of land that was recovered from high levels of salinity<br>2. NA<br>3. low, need for government support<br>4.high, the implementation on large scale was supported by the national government<br>5.medium, the agricultural communities were trained to be able to practise integrated farming methods that included the excavation of dykes around agriculture plots<br>6.medium, with the support of government agencies and NGOs, the community people came up with the integrated farming method<br>7. NA |

**Table 3** (continued)

| Country and title of case study | (Key) Benefits derived Based on:<br>1. Innovation;<br>2. Evidence of effectiveness<br>3. Sustainability<br>4. Political will and local ownership<br>5. Community-based adaptation<br>6. Multi-stakeholder collaboration, efficient division of tasks<br>7. Influence/spill-over effect and replicability: |
|---|---|
| Kenya<br>Building resilience to climate change: supporting self help groups to construct sand dams to capture and store rainwater | 1.medium, localities are transformed by the creation of new physical infrastructure that retains water and allows for water management in the community<br>2. NA<br>3.high, communities are trained in using climate smart farming techniques, including terracing, establishing tree nurseries, and planting drought tolerant crop varieties<br>4. NA<br>5. high, good degree of community involvement<br>6. NA<br>7.high, the model is highly replicable and scalable, programmes were successfully implemented in northern Kenya, Zimbabwe, and Mozambique |
| India<br>Going back to roots: resilience of Kharchia wheat | 1.low, the initiative was fundamentally behavioural, as other farmers were encouraged to shift their preference to the indigenous variety<br>2.high, since presently more than 132 farmers in 8 villages are growing the variety and facilitating the transition to more productive, sustainable and inclusive food systems<br>3. high, mainly for being a behavioural action<br>4. NA<br>5. NA<br>6. NA<br>7.high, the crop's success led to over 132 farmers growing the indigenous crop leading to a 33–48% increase in income and increase of 33–48% of production in these farms |
| Honduras<br>"Los Limones" CEPIRS, a climate change resilient farm | 1.medium, the project introduced a range of low-cost technological solutions coupled with sustainable farm design<br>2. NA<br>3.high, the project encourages adoption of more cooperative behaviour among farmers to preserve the watershed as a common resource for soil management purposes<br>4. NA<br>5. NA<br>6.high, the initiative was carried out in collaboration with development NGOs for a single farm community<br>7.high, it is possible for other farmers to adopt these new methods (upscale) if there are visible and affordable/cost effective options |

Alkaya et al. (2015) (Turkey), AHRED (2021) (Migori County (Kenya), Rodríguez-Rigueiro et al. (2021) (Spain), Saroar et al. (2019) (Bangladesh), AsdAfrica (2021) (Kenya), Casri (2021) (India), and iDE (2019) (Honduras)

All the assessed case studies address a grave concern in their respective regions; for example, the Turkish case study refers to a critical need identified by the private sector whereas the Migori county case study from Kenya addresses climate change induced drought. The importance of technological innovations for adaptation has been recognized for a long time (e.g. Adenle et al. 2015). Existing gaps, especially in the area of climate prediction and climate modelling, may be filled by applying machine learning and artificial intelligence to climate change adaptation; recognition of untapped potential and a need for interdisciplinary collaboration are some key requirements (Rolnick et al. 2019).

Several case studies are characterized by distinctive features of *community-based adaptation (CBA)* which might be also be considered a typical trait of TA. In a CBA context, designing such transformative interventions with the affected and potentially collaborating communities might enhance their success (Dodman and Mitlin 2013; McNamara et al. 2020). Case studies like the wetland restoration and hydroponic agriculture case in Bangladesh illustrate this collaborative setting. Effective TA at a community level requires the identification of those challenges that are most pressing to communities, usually those that impact people's livelihoods (Ensor and Berger 2009), and investigating if a community may already have own solutions at hand but may just lack the means to implement them (Schipper et al. 2014). For example, in the Migori county (Kenya) case, farmers co-developed the adaptation action, and in the Bangladesh case of Integrated Farming, it can be seen that the affected community developed their own solution.

Considering the relevance of place attachment is a further factor to be considered, and it should be carefully assessed what a driving force this may be for taking ownership of TA interventions by the involved communities (Ayers and Forsyth 2009). As a notable example, the Fiji government developed a complex guidance to planned climate changed induced relocation, considered the before-mentioned aspects throughout the planning and implementation processes, resulting in successfully relocated communities (Fiji 2019). From the selection of case studies, it might be concluded that the TA pursued should be grounded in a strong feeling of place attachment as the actions pursued support securing working and living conditions in the respective locations. Some notions of government involvement may refer to public ownership yet it is difficult to judge the extent to which this is reflected in local ownership of the adaptation action.

Another commonality observed in the case study evaluation is the *concerted approaches* to the identified problem. This points towards the efficacy of collective action that may be created by means of multi-stakeholder collaboration and efficient allocation of tasks. Sherman and Ford (2014) report research-based intervention designs coupled with active community co-management involvement, something that was highlighted in the case study from Bangladesh. Institutional innovations, especially at a local level, also appear to be crucial for adaptation, in particular as "efforts to generate appropriate adaptation responses require institutional arrangements that empower the stakeholders to co-produce the technologies needed to address the new challenges" (Rodima-Taylor et al. 2011:109).

The success of TA may also be linked to the creation of so-called *win–win interventions*, that consider the need for sustainable livelihoods through either supporting existing practices or creating new ones adapted to community contexts; when businesses are involved, their buy-in is required (Biagini and Miller 2013; Ojea 2015). Turkey's case study shows how enhanced environmental sustainability and resource management were coupled with a high return on investment (costs for interventions were offset after just 6.8 months). Yet what this case study does not show is whether the businesses would have agreed to change production practices if the projected yield was lower than before.

**Table 4** Adaptation of actors/sectors and its context/content

| Nr | Location | Adaptation of Actors/Sectors | Adaptation Context and Content |
|---|---|---|---|
| 1 | Turkey | Private companies and cross-sectoral | Adapting to water scarcity and resource material constraints |
| 2 | Migori county (Kenya) | Agriculture | Adapting to draughts and reduced soil moisture |
| 3 | Galicia, Extremadura and Cataluña in Spain | Agriculture | Adapting to draughts and heatwaves |
| 4 | Bangladesh | Coastal settlements | Adapting to sea-level rise and storm surges |
| 5 | Bangladesh | Coastal settlements | Adapting to sea-level rise and storm surges |
| 6 | Bangladesh | Coastal settlements | Adapting to water scarcity and poorer nutrition in wetlands |
| 7 | Bangladesh | Farmers | Adapting to droughts, salinity |
| 8 | Kenya | Farmers, remote communities | Adapting to droughts, soil aridity |
| 9 | Rajasthan, India | Agriculture | Adapting to droughts, soil aridity/ salinity |
| 10 | Honduras, Central America | Agriculture | Adapting to droughts, food insecurity |

The detailed assessment also provided some insights on the potential for *spill-over effects and replicability*, that is identifying those traits which may profoundly influence sustainable development. Six of the 12 case studies scored 'high' and four scored 'medium' on this indicator, from which it could be argued that the transfer of knowledge and the replicability of the identified adaptation action are key factors for TA actions, ultimately leading to upscaling of such sustainable solutions. The Bangladesh cases may be regarded as being at least as relevant for their Indian neighbors; spill-over and replicability are linked to the mechanisms that make them replicable in other parts of the world (Reid and Schipper 2014).

### 3.2 Discussion

One of the objectives of this paper is to present findings arising from selected case studies, to identify key characteristics, possibly patterns, which can foster TA. This is even more relevant, and urgent, given that today the pace of climate change has accelerated, and requires adaptation measures to be effective and sustainable, crucial elements to promote TA. One of the findings that this review shows is that the nature of contemporary/recent optimal TA varies from place to place and, as discussed below, it needs not be sudden (it can be gradual) and it is often better to be autonomous rather than top-down. Figure 1 provides an overview of key features in TA.

Given that in the future it is likely that there will be catastrophic (tipping-point) events, attributable to climate change, which will trigger TA among communities that had previously been sceptical or hesitant to participate (Rauter et al. 2019), the findings can be interpreted with this specific understanding. In this regard, seven out of the ten projects were driven by climate hazards (mainly droughts and flooding), and at the same time, the project had also an element of community participation, indicating some degrees of sudden TA. Sudden TA is sometimes unavoidable (Lonsdale et al. 2015; Munene et al. 2018). When a volcano erupts, people in surrounding areas may be quickly relocated and may sometimes be unable to return to the places they formerly lived (Jibiki et al. 2019). Something similar happens when large dams are built and once-inhabited areas flooded, although the human impact can be lessened by staggered relocation (Zeitoun et al. 2019). A further element to consider is that many projects reviewed above had an active involvement of government authorities, which seemed to have preferred to invest in achieving short-term adaptation goals as part of a longer-term strategy to attain TA (Moser and Ekstrom 2010). It is yet to be understood if this active role played by government authorities is the result of a long-term planned adaptation strategy, or born from the reactive need to spend climate funds provided by donors.

One of the keys to successful TA is the scope of the adaptation, meaning that the central elements such as the involvements of the stakeholders are not overlooked. And this is context-specific. For a community of a hundred people on a small island, the relocation of that community and its subsistence economy may be a truly transformative event in the minds of the affected people even though the associated costs are comparatively small (Dodman and Mitlin 2013; McMichael and Katonivualiku 2020). Yet in the same way, nation-wide plans costing billions to remove hundreds of thousands of vulnerable people and infrastructure from exposed coastal locations is transformative in the sense that it is ambitious, visionary and will force fundamental changes to many people's lives (Oudes and Stremke 2020). The case studies reviewed in this paper did not involve relocations; therefore, one cannot interpret the results in the light of this important element that shall drive most of

the future discussion on TA. However, the majority of the projects discussed above are presenting 'effective' solutions to possibly avoid relocations in the near future, hoping that mitigation measures and development patterns will limit the impact of natural hazards.

A further crucial aspect emerging from the literature is that the cooperation of everyone driving and affected by TA projects of this kind is essential to their success. This raises issues of social justice (Lonsdale et al. 2015), and it is being increasingly recognized that affected people should be fully engaged from the outset in (non-sudden) TA (Granberg et al. 2019). A good number of projects discussed above seem to feature important elements that confirm the active involvement of communities, and key stakeholders, in 'owning' adaptation initiatives, by leaving those who fund/drive them taking a back seat. Recent work that has reviewed this same approach, involving vulnerable communities in the Pacific, considered it central to promote climate change adaptation (McNamara et al. 2020; Westoby et al. 2019).

This point is further illustrated by the ways of conceptualizing TA, whether specifically it is a case of 'adapting to' or 'adapting with' (Perez-Catala 2014). In the 'adapting to', the environment is the external factor, while the interest lies in the response of the existing system, when confronted with higher risk and vulnerability potential (Rickards and Howden 2012; Kates et al. 2012). In the 'adapting with', socio-ecological systems react to change by co-developing reactions, and therefore, the investigation of the societal sources vulnerability plays a pivotal role. 'Adapting with' creates the illusion that people have an influence over the economic, political, and social factors responsible for the vulnerable environmental condition which may not realistically be the case (Rickards and Howden 2012; Perez-Catala 2014).

Arising from this, a final point is the question of how best to drive TA, especially if the process is gradual, even taking decades rather than months or years (Rippke et al. 2016). In democratic countries where the costs of TA may be considerable and where its gradual manifestations may be increasingly unpopular, there is a real challenge in ensuring the process is complete. The key to ensuring successful TA may therefore lie in empowering people, largely through education and awareness-raising, to understand both the need for TA and the benefits it will bring, first and foremost in support of securing working and living conditions in a sustainable manner (Alam and Miller 2019; Bazart et al. 2020; Iturriza et al. 2020). The lessons arising from the projects discussed above paint a complex picture, where promising elements in terms of community involvement and government intervention provide hope for the adoption of measures fostering TA. However, the context-specificity of these solutions and the need to extend the sectoral and geographical breadth of such investigations leaves little room for generalizations, and calls for further research to be promoted.

## 4 Conclusions and lessons learned

This paper defines and characterizes the concept of TA and outlines how it might inform current and future climate change adaptation challenges. Assessing a set of case studies to understand their potential transformative impact, the authors also provide a set of examples to illustrate how this innovative approach can be implemented in practice. Some common traits to support the future sustainable deployment of TA are identified.

The implications of the paper are two-fold. Firstly, the case studies illustrate the diversity of elements associated with transformative changes. Secondly, whereas this is an area

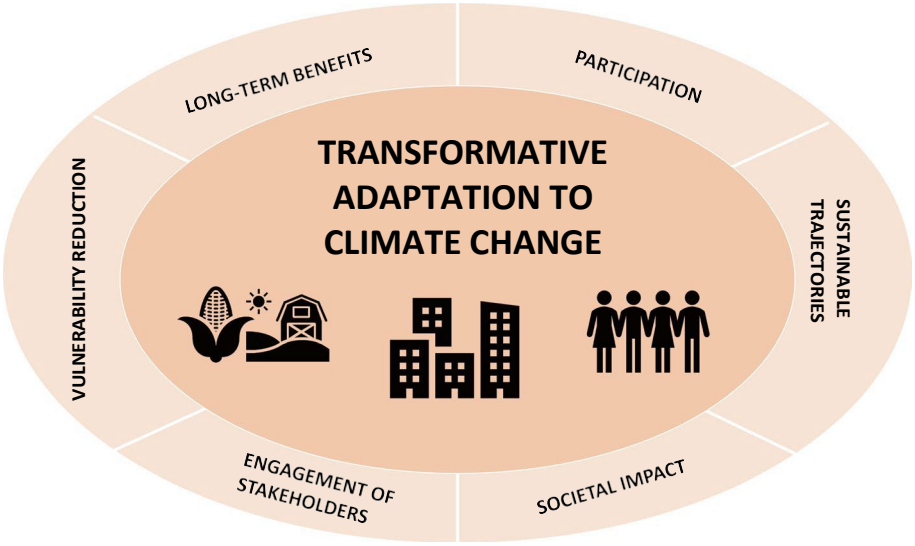


**Fig. 1** Some of the features of TA. Source: authors' own compilation

still evolving, TA is inescapably interdisciplinary and will require further refinement, especially in the conceptual framings of the complex fundamental systemic changes needed to better capture its context-specific applications and impacts. Many more examples of successful TA are needed to inspire replication and upscaling, and to strengthen the narrative that every individual's action counts towards keeping global climate change manageable and allowing human society to develop sustainably.

As TA is increasingly being proposed as a sustainable approach to managing unavoidable climate change risks, appropriate adaptive management strategies need to be developed and implemented, integrating multi-stakeholder perspectives, using modern tools and respecting individual livelihood preferences such as place attachment in the quest for acceptable solutions to the challenges faced, especially in developing countries. Moreover, a multi-stakeholder collaboration that aims at creating win–win situations, combined with a close monitoring and evaluation of on-going adaptation action may be required, to assess not only interim progress and short-term results, but also win and retain public acceptance and local ownership to enable maintaining desired functions of socio-ecological systems and adapting to biophysical changes.

The study has some limitations. One of them is that the findings come from only a small sample and also do not cover the whole spectrum of approaches to TA. Nonetheless, the research helps to shed a light on the spectrum of examples, geographically as well as thematically. More long-term research is needed to scrutinize adaptation actions and identify potentially transformative leverage. The suggested analytic lenses allow a quick means of scrutinizing potentially TAs by taking an interdisciplinary approach to assessing its characteristic features, that is by integrating climate science with managerial (monitoring and evaluation) perspectives. Yet for more qualified claims and reliable results of such evaluations, it is recommended to further improve and develop corresponding frameworks and indicators, especially those which are fully in line with the local conditions within which TA is expected to be implemented.

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