

Towards more sustainable responses to natural hazards and climate change challenges via transformative adaptation

Walter Leal Filho^{a,b}, Amanda Lange Salvia^c, Abdul-Lateef Balogun^{d,e},
Mário Jorge Verde Pereira^f, Serafino Afonso Rui Mucova^{f,g}, Oluwadunsin Moromoke Ajulo^h,
Artie Ng^{i,j}, Juliet Gwenzi^k, Emmanuel Mashonjowa^k, Yusuf A. Aina^{l,m,*}, Chunlan Li^{n,o},
Edmond Totin^p, Patricia Pinho^q, Donovan Campbell^r, Nelson Chanza^s, Andréia F.F. Setti^f

^a Department of Natural Sciences, Manchester Metropolitan University, Chester Street, Manchester M1 5GD, UK

^b European School of Sustainability Science and Research, Hamburg University of Applied Sciences, Germany

^c University of Passo Fundo, Graduate Program in Civil and Environmental Engineering, BR 285, Passo Fundo, RS, Brazil

^d Services Department (Resources), Esri Australia, 613 King Street, West Melbourne, VIC 3003, Australia

^e Geospatial Analysis and Modelling Research (GAMR) Group, Department of Civil & Environmental Engineering, Universiti Teknologi PETRONAS (UTP), 32610 Seri Iskandar, Perak, Malaysia

^f Department of Biology & CESAM (Center for Environmental and Marine Studies), University of Aveiro, Portugal

^g Faculty of Natural Sciences, Lúrio University, P.O. Box 958, Pemba, Mozambique

^h University of Newcastle, Australia

ⁱ Centre for Sustainable Business, International Business University, Toronto, Canada

^j Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hong Kong SAR

^k University of Zimbabwe, Harare, Zimbabwe

^l Department of Geomatics Engineering Technology, Yanbu Industrial College, Yanbu, Saudi Arabia

^m Geoinformatic Unit, Geography Section, School of Humanities, Universiti Sains Malaysia, 11800 Penang, Malaysia

ⁿ Center for Geopolitical and Strategic Studies & Institute for Global Innovation and Development, East China Normal University, Shanghai 200062, China

^o School of Urban and Regional Sciences, East China Normal University, Shanghai 200241, China

^p Université Nationale d'Agriculture du Bénin, Kétou, Benin

^q Institute for Advanced Studies (IEA), University of Sao Paulo, Brazil

^r Department of Geography and Geology, The University of the West Indies, Mona, Kingston 7, Jamaica

^s Department of Geography, Energy Studies and Environmental Science, University of Johannesburg, South Africa

ARTICLE INFO

Keywords:

Transformative adaptation
Sustainability responses
Natural hazards
Poverty–livelihood nexus
Climate change

ABSTRACT

Climate change is perceived as a major challenge of modern times. Apart from mitigation measures, such as greenhouse gas emission reductions, a further means to tackle it is via the deployment of adaptation policies and responses, which may also help to address the natural hazards associated with it. Despite the importance of adaptation measures, their effectiveness is often limited by a failure to integrate actions addressing both the causes and symptoms of vulnerability. There is evidence that adaptation processes are largely fragmented, incremental, with limited capacity for transformational change. This paper suggests measures through which transformative adaptation may be further deployed to tackle climate challenges in conjunction with efforts that address poverty alleviation. The implications of this paper are two-fold. Firstly, it offers a comprehensive review of the literature on transformative climate change adaptation, outlining its nature and special features. Secondly, it contains a unique set of cases from 20 countries, predominantly from the Global South, mostly affected by climate change, and is one of the largest studies on the topic ever undertaken. The experiences from this paper will support attempts to sustain transformative adaptation and natural hazards control, which are relevant to the many countries suffering from climatic variations.

* Corresponding author at: Department of Geomatics Engineering Technology, Yanbu Industrial College, Yanbu, Saudi Arabia.

E-mail addresses: walter.leal2@haw-hamburg.de (W.L. Filho), amandasalvia@gmail.com (A.L. Salvia), geospatial63@gmail.com (A.-L. Balogun), mverde@ua.pt (M.J.V. Pereira), serafinomucova@live.ua.pt (S.A.R. Mucova), Oluwadunsin.ajulo@uon.edu.au (O.M. Ajulo), ang@ibu.ca (A. Ng), julievimbai@gmail.com (J. Gwenzi), emashonjowa@gmail.com (E. Mashonjowa), ainay@rcyci.edu.sa (Y.A. Aina), 15598022233@163.com (C. Li), edmond.totin@gmail.com (E. Totin), pinhopati@gmail.com (P. Pinho), donovan.campbell@uwimona.edu.jm (D. Campbell), nchanza@gmail.com (N. Chanza), andreiasetti@gmail.com (A.F.F. Setti).

<https://doi.org/10.1016/j.cities.2023.104525>

Received 1 October 2022; Received in revised form 4 July 2023; Accepted 5 August 2023

Available online 15 August 2023

0264-2751/© 2023 Elsevier Ltd. All rights reserved.

1. Introduction: contextualising transformative adaptation

Climate change adaptation has been discussed for many years in relation to topics such as the efficient use of water resources and flood defences, the adaptation of building codes to extreme weather conditions and the development of drought-tolerant crops (Aguar et al., 2018; European Union, 2014; Lesk et al., 2016). Many of these actions referred to changes within the current system to address either the causes or symptoms of vulnerability. More recently, there have been calls for system transition to enable more transformational adaptation to climate change and its impacts (IPCC, 2018). Although some publications use the terms transformative and transformational interchangeably, in this article, we consider that transformational refers to the outcome of a process, while transformative is about the features of the process that enable the outcome. Few et al. (2017) highlight some further subtle differences. While transformational adaptation represents the transformation of the adaptation practice, transformative adaptation is more related to an adaptation that generates transformation, which includes innovation, expansion, reorganisation, and reorientation of societal values (Few et al., 2017). These expressions are not exclusive terms, however, so the same action can represent both a transformational and a transformative adaptation, and their basic characteristics are similar. Kates et al. (2012) distinguish three forms of transformational changes: (i) those that are adopted at a larger scale, (ii) those that are new and have never been used in a particular system, and (iii) those that transform places and shift locations. Further, Kates et al. (2012) explain that transformational changes can be the outcome of either collective or individual changes, both autonomous and explicitly planned.

Huq (2017) presents transformative adaptation as the third and theoretical phase of adaptation to climate change. He notes that the first phase includes identifying and stopping maladaptation to future impacts, based on initial vulnerability assessments and actions that are enhancing vulnerability rather than reducing it. The second phase is characterised by incremental adaptation, and it looks at existing and planned investments and includes actions to make them more adaptive to the impacts of climate change. Arguably the second phase reflects the current status of adaptation. Transformative adaptation is Huq's third phase and is characterised by innovation, extending beyond incremental changes to manage additional risks and focus on systemic changes. Transformative adaptation acknowledges that climate change does not operate in a silo, and that transformation requires radical changes to the status quo. It considers outcomes of interventions such as investing in education, professional training and opportunities and in empowering people to become agents to enhance resilience to climate change (Huq, 2017), and it questions the entire systems, metrics and values against which progress and development are assessed.

Transformative approaches to climate change adaptation are considered fundamental, systemic changes that contribute to protecting development gains, maximising resilience and reducing the escalating risk of conflict from climate change (World Resources Institute, 2019). The nature of a transformative adaptation is both reactive and anticipatory, autonomous and planned, with the possibility of being collective, individual, or organisational (Mustelin & Handmer, 2013). And it may require public policies that appeal to a logic of both mitigation and adaptation, and it may help people to recognise the link between them (Brink & Wamsler, 2019). Such a dramatic shift demands important capacities, which include leadership for transformation, capacity for systemic inquiry and learning from practice (Catrien et al., 2017; Lonsdale et al., 2015). It also requires the re-framing of adaptation research and practice (Wise et al., 2014) and a re-imagining of the future, as well as efforts to initiate the adaptation and sustain it over time (Kates et al., 2012). Transformative adaptation is necessarily multi-scale and multi-disciplinary, requiring regional actors to extend their scientific modelling expertise to public policy, land use planning and social science spheres (Shi, 2019).

Transformative adaptation is not, however, straightforward. The difficulty of applying this approach is not only related to the need for systemic change; it is also connected to the uncertainties about climate change risks and adaptation benefits (Vermeulen et al., 2013), the high (short and medium-term) costs of transformative actions, and the institutional and behavioural actions that tend to maintain existing resource systems, power structures and policies (Kates et al., 2012). Kates et al. (2012) present three classes of adaptations that target transformation: (i) those that are adopted at a large scale or intensity, (ii) those that are truly new to a particular region or resource system, and (iii) those that transform places and shift locations. Within these classes, all of these adaptations can be responsive or anticipatory, technological or behavioural, collective or autonomous.

Recent reports on global warming from the Intergovernmental Panel on Climate Change (IPCC) present transformative change as essential if we are to limit warming to 1.5 °C above pre-industrial levels, noting also that it is important to integrate it with sustainable development and complementary transformative adaptation, as incremental adaptation is insufficient to address the impacts of climate change (IPCC, 2018). Many studies have been focusing on transformative adaptation approaches and their importance in tackling climate change in different contexts (Colloff et al., 2017; Ghahramani & Bowran, 2018; Mechler & Schinko, 2016; Ghahramani & Moore, 2015; Ghahramani & Moore, 2016; Pelling et al., 2015; Rippke et al., 2016; Solecki et al., 2017).

As Fig. 1 shows, the field of transformative adaptation changes the dynamics and structure of systems, their economic, social and political relations, as well as the individual and collective beliefs and behaviours. The interaction among knowledge, culture and governance mechanisms, and in some cases among incremental, transformational and transformative adaptation, determines whether or not the system is capable of creating resilience to the challenges of climate change and natural disasters.

For Revi et al. (2014), urban centres need to shift from adaptation and resilience to transformative adaptation that includes limiting or reducing greenhouse gas emissions, addressing also the root causes of poverty and failures in sustainable development and demanding the competence, capacity and willingness of local government to act on adaptation. Additionally, transformative adaptation requires new ways to evaluate and manage trade-offs between maintaining desirable aspects of current social-ecological systems and adapting to major biophysical changes in those systems (Colloff et al., 2017).

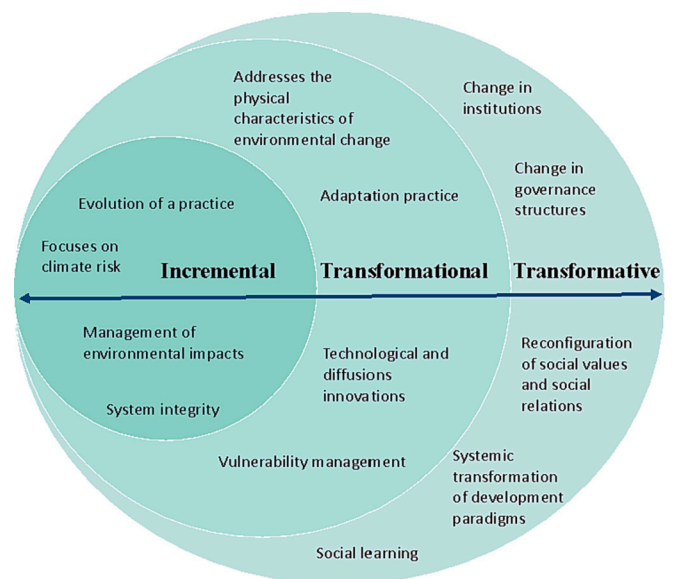


Fig. 1. Characteristics of Incremental, Transformational and Transformative adaptation.

Transformative adaptation should be considered a challenge to the specific social structures and processes that support economic hegemony (Warner & Kuzdas, 2017) and a key focus of diverse empirical and theoretical research on climate adaptation (Shi et al., 2016). Nevertheless, it remains unclear how transformative adaptation influences current and future climate change adaptation challenges. This paper takes up this challenge, departing from the following problem statement: whereas transformation in climate change adaptation entails changes in human and environment systems in order to adapt to changing climate conditions, the extent of such changes is not sufficiently analysed or documented.

This research gap means that there are few opportunities to learn from such experiences. This paper addresses this problem and comprehensively describes some of the many variables that characterise transformation in a climate change context, and then presents various cases that illustrate how transformative adaptation is being implemented. This unique and comprehensive set of cases may, in turn, not only exemplify how transformation is taking place but also inspire further initiatives.

2. Usefulness of transformative adaptation and sustainable responses

Transformative adaptation is increasingly being suggested as a sustainable approach to managing unpreventable climate change risks. Climate change adaptation is basically seen as increments of adaptation to climate and its natural variation, aimed at preventing the systems' destabilisation or malfunctioning at their present locations. However, in some instances the magnitude of vulnerabilities and risks may overwhelm otherwise robust resource systems. Such peculiar situations require transformational rather than incremental adaptations (Fedele et al., 2019; Hölscher et al., 2019; Kates et al., 2012). Although it is still largely in the stage of theory rather than implementation (Huq, 2017), evidence of the potential benefits of transformative adaptation is beginning to emerge. For instance, salinity intrusion caused by Sea Level Rise (SLR) has been identified as a major climate change risk to millions of residents in Bangladesh's low-lying coastal zones. Pregnant women are particularly vulnerable to the impacts of saline water consumption, and the provision of clean water has been proposed as an ideal incremental adaptation strategy. Pushing the boundaries further, the vulnerable women population could become change agents for the entirety of the country by prioritising their education in a radical departure from existing practice. Large-scale investments in quality female education may equip the vulnerable women population with the skills needed to make them employable and the resources to move away to less vulnerable towns and cities, away from the hazardous coastal regions. In the long term, it is anticipated that the effects of such investments, including generating educational and employment opportunities in towns further inland, will trigger voluntary relocation away from vulnerable areas, thereby boosting climate change resilience via transformative adaptation.

A study by Clarke et al. (2018) suggested that transformative adaptation can enable a pathway for place change, and when aided with educational awareness, adaptation will occur despite challenges posed by place attachment in most communities. Kates et al. (2012) identified a high level of vulnerability in some places as one of the conditions for transformative adaptation, and complete relocation from such high-risk places might be the only viable alternative. It is important to note that people with less affinity for a place have a higher likelihood to adopt transformative adaptation requiring migration from high-risk areas (Marshall et al., 2016). In the recent past, a nationwide family planning education initiative was well received by the female population, and it was able to reduce the population growth rate from over 3 % to less than 2 % over a single generation (Huq, 2017). Transformative family planning is essential in countries like Bangladesh, where the high unemployment rate is one of the chronic stressors that weaken the society's fabric and resilience.

Another major advantage of transformative adaptation is the enlarged scale of deployment, bringing benefits to a much larger population than usual. For instance, the natural regeneration/regreening of the Sahel by farmers to address drought-induced farming problems is very popular in the region, with about 5 million hectares in the climate change resilient green belt. Such widespread adaptation with much larger effects is synonymous with transformative adaptation and sustainable responses (Kates et al., 2012). Transformative adaptation also supports anticipatory initiatives that entail planning for future risks long before they occur. The UK's Thames Estuary 2100 Plan envisions transformative strategies for SLR by constructing an enhanced barrier at a separate place, in addition to avoiding construction in flood-prone areas after 2060. Such well-thought-out long-term plans enable the local authorities and residents to cope well with future risk scenarios, thereby enhancing the city's sustainability. Transformative approaches equally support innovative concepts, which could be entirely novel or an integrated combination of existing concepts and resources by various collaborators to be deployed in new locations. For example, crop insurance against weather loss, which hitherto existed in developed countries, is now being implemented in a couple of developing countries.

Agriculture is undoubtedly a major beneficiary of transformative adaptation as a means of a sustainable response to climate change. Based on UN projections, 6.5 billion people will be living in cities by 2050, and global food security is endangered due to the growing urbanisation that causes people to migrate from traditional agricultural centres to urban areas. In the U.S. alone, less than 3 % of the population is involved in productive farming, and 60 % of these farmers are about the age of 60 (Harper, 2016). Transformative initiatives for adaptation in the agricultural sector are essential to strengthen global food security. It will also be required to prevent maladaptation and to minimise risks associated with conflicts. Current adaptation practices in the agriculture sector offer relatively limited incremental adjustments to existing systems. However, the rise in extreme climate and weather events are beginning to neutralise the gains of such relatively minor adjustments (Carter et al., 2018). The scale, novelty and holistic measures provided by transformative adaptation are thus required to manage these impacts and minimise risks, enhance food security and preserve the livelihoods of vulnerable communities. A spike in demands for new adaptation initiatives to protect communities is anticipated as climate change threats increase in frequency and intensity (Hess et al., 2008). It is becoming evident that these demands cannot be entirely met by incremental adaptation, which underscores the significance of transformative adaptation in sustainable climate change adaptation.

Transformational adaptations address large-scale interventions based on flexible rather than 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 require adequate responses, it is quite common to detect development actions that fail to address stimulants or that handle the source of vulnerability. As a result, the end change is often superficial (Warner et al., 2019). Transformative adaptation will be gradually more significant in successfully mitigating the impacts of climate change and other global burdens that put pressure on social-ecological systems. New evaluation and managerial techniques are necessary in order to further develop transformative adaptation while maintaining desirable levels of social-ecological systems and the ability to adapt to relevant biophysical alterations (Colloff et al., 2017).

Thornton and Manasfi (2010) imply that transformative adaptation is described as the radical approach in relation to the conventional ones, while Moser and Ekstrom (2010) refer to a spectrum of short-term ones that lead to long-term deeper transformations. Perez-Catala (2014) mentions that basically 'adapting to' and 'adapting with' happen to be the two defined distinctions of change (Pelling & Dill, 2010). In the 'adapting to', the environment is the external factor, while the interest

rests on the response of the existing scenario when confronted with higher risk and vulnerability potential by adapting to situations maneuvered by scale or intensity increases of the approaches in effect (Kates et al., 2012; Rickards & Howden, 2012). In the 'adapting with', the socio-ecological systems react to change by co-developing reactions, and therefore the investigation of the vulnerability of the societal source plays a pivotal role (Rickards & Howden, 2012). When searching for transformative adaptation definitions, it should be taken into consideration how the fundamental aspects interact, while also analysing elements such as governance (Aina et al., 2019), equity and sustainability. 'Adapting with' instead of 'adapting to', which is considered external, gives the illusion that people have an influence over economic, political and social factors responsible for the vulnerable environmental setup (Perez-Catala, 2014; Rickards & Howden, 2012). This brings up the importance of fair and ecologically sustainable decision-making (Lonsdale et al., 2015) in climate change adaptation contexts. Fig. 2 shows the importance of coordination in the implementation of development measures that promote equity and sustainability with adaptation measures that reduce the damage caused by climate change.

Planned adaptation happens to be a way to reach sustainable societies, dealing with greenhouse gas emissions and reducing vulnerability to climate change. Transformative adaptation is the rapid response when we experience extreme or rapid climate changes. Populations in such situations are extremely vulnerable to fundamental changes (Kates et al., 2012; Lonsdale et al., 2015). Sustainability based on adaptation policies and practices can result in consequences that have been given little attention (Eriksen et al., 2011). An example proving the above statement is the set of present adaptations for the global warming problem, many of which focus on short-term control of local environmental conditions, hoping to change weather conditions by, for instance, influencing energy use (Eriksen & Brown, 2011).

In our hurry to successfully implement adaptation strategies to climate change, we often undermine the economic, social, and environmental objectives associated with sustainable development. Trying to boost sustainability for one group, often we jeopardise the

sustainability of another one. Biodiversity often gets neglected in our eagerness to moderate climate risks, through specific technologies or infrastructural changes (Eriksen & Lind, 2009; Eriksen & O'Brien, 2007). Adaptive responses can have unintentional consequences on people and the environment, especially when we only focus on climate change threats as a stand-alone process without weighing the potential effects of the chosen strategies on the other sectors of the society (Eriksen & O'Brien, 2007). Climate adaptation could also bring to light the shortcomings of conventional economic and social development systems that are charged with the generation of problems related to poverty, inequity, and environmental degradation. Synergies among sustainable development and adaptation can offset poverty and environmental issues besides climate change, which has not been given appropriate consideration (Eriksen et al., 2011).

Environmental efficiency (Korhonen & Seager, 2008), as well as incremental change (Konnolla & Unruh, 2008) perpetuate trajectories that cannot assure sustainability. Climate change is challenged by the above-mentioned trajectories and socio-technical systems, and the trajectories may be exactly the prerequisite to adequately address the challenge of climate change (Burch et al., 2014; Rotmans et al., 2001).

Climate goals will only be met if policies embed deep changes; otherwise, achieving climate goals will be expensive and disruptive to unachievable levels (Morita et al., 2000; Swart et al., 2003). In order to successfully integrate climate policy, sustainability goals related to economics, technology, social dimensions and the environment must be met (Robinson et al., 2006). Sustainability is by definition woven throughout a broad range of policy priorities (Burch et al., 2014).

Climate change is both an opportunity and a threat, revealing the true image of sustainable development risk (CCCD, 2009). Precipitation or hydrological regimes, while benefiting some, adversely affect vulnerable groups at the same time (Barnett & O'Neill, 2010). Changes in adaptation policies and interventions have become an urgent priority if we plan to reduce climate sensitivities and pursue the enforcement of strong sustainability responses (Eriksen & O'Brien, 2007). Adaptation, when socially and environmentally sustainable, is a way to work

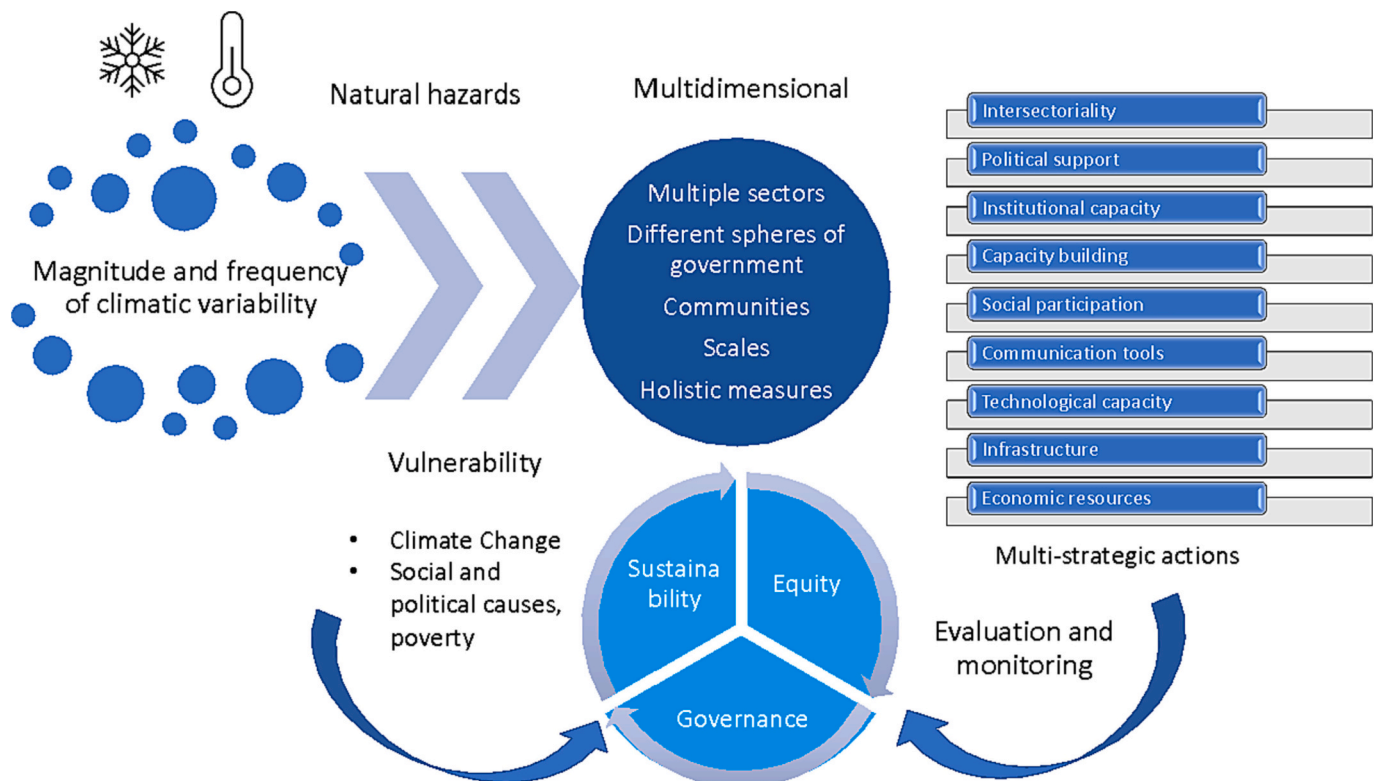


Fig. 2. Transformative adaptation approach to address current and future climate change adaptation challenges.

towards the reduction of poverty and vulnerability (Eriksen & Brown, 2011).

Smith (1997) emphasised the need for flexible and resilient adaptation, rather than reactive, where the benefits will also exceed the cost if we truly aim at social vulnerability reduction. Adaptation is seen as a parallel to resilience, transition and transformation concepts (Colloff et al., 2017; Pelling & Dill, 2010).

Pressure from recent developments and infrastructures has moved place attachment processes to higher priority, proving that proactive adaptation is more acceptable and fairer for individuals. Transforming places involuntarily because of extreme weather events or the absence of community involvement in decision-making processes has stigmatised the sustainable development of the affected ones. Populations should become partners and not apathetic recipients of adaptation planning in order to actively cooperate in the best possible solution.

3. Methodology

This paper identifies the extent of transformative adaptation being implemented in different countries around the world, the readiness level of the countries and the challenges to transformative adaptation therein. The hypothesis guiding this paper is: “developing countries pursue incremental adaptation because of various limitations, other than financial constraints.”

The theoretical framing of the study is based on three main elements: the resilience theory (which emphasises the capacity of systems to absorb shocks, adapt to changes, and maintain their basic functions); adaptive capacity (to explore how incremental changes in social, economic, and ecological systems contribute to building resilience over time) and the path dependence theory which suggests that past decisions and actions shape current and future adaptation pathways.

Two approaches were used to collect information about transformative adaptation and the analysis of the case studies. The first approach combined a desk study, literature analysis and the authors' observations. The approach involved a literature search from databases, government publications and newspaper articles. The relevant literature was identified, and the contents were mapped to extract information using a set of questions about the prevalence of climate hazards and the responses to the various climate problems. The framework for the literature search presented by Healey and Healey (2016) was adopted when extracting relevant information from the literature. The case analysis was conducted in 20 countries across the world. Each country is considered a unit of analysis (Yin, 2003). The selection of these countries was premised on the following criteria: 1) Vulnerability to climate change; 2) Geographical, cultural, and socioeconomic variation; 3) Expertise of the participating researchers and access to field survey data for validation.

Because developing countries are relatively more vulnerable to climate change (Leal Filho et al., 2019), the bulk of cities assessed in this study was selected from Asia and Africa, two of the continents with a sizeable number of vulnerable developing countries (UN DESA, 2022). Also, to account for variations in climate zones and peculiarities of socioeconomic, environmental and cultural challenges in different localities, the study considered the geographical distribution of countries in significantly diverse continents (e.g. Africa, Asia, Europe, and Oceania), selecting countries of different sizes, ranging from sparsely populated ones such as the Maldives to highly populated countries like India and China. Further, the ability of the research team to acquire primary data was prioritised in selecting some of the study locations. Thus, in addition to gathering evidence from the literature and collecting existing data, researchers who participated in this study also conducted surveys and discussions with local specialists in selected countries.

The 20 selected countries include Bangladesh, Burkina Faso, Cambodia, China, France, India, Iran, Jamaica, Maldives, Kenya, Morocco, New Zealand, Pakistan, Saudi Arabia, Solomon Islands, Spain, Tunisia, Vietnam, Zambia and Zimbabwe. For the second approach, field surveys were deployed in seven of the selected case countries

(Bangladesh, India, Maldives, Morocco, New Zealand, Tunisia, and Zimbabwe) to further verify the information collected so far. It is noteworthy that the selection of this field survey sample is based on convenience, determined by the ability of the research team to accurately acquire primary data within a reasonable time frame.

This is based on the information and knowledge gap that needs to be addressed, especially with respect to what happens in individual countries. The case studies examine the diversity of context, including geographical, cultural, socio-ecological and socio-environmental systems, as well as different governance and political frameworks and how these may influence their vulnerability. They were used to ascertain the extent to which adaptation interventions may help in enabling transformative change, using a set of indicators. This systematic selection and distribution of case studies in multiple countries (Fig. 3) helps to deepen the understanding of global transitive efforts and paths towards transformative adaptation.

The statistical analysis of the data was performed with the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were analysed to find trends and classify the adaptation strategy in each of the 20 countries involved into incremental, transformational and/or transformative approaches. The analyses performed also served the purpose of describing the mode of transformative adaptation among the geographical regions.

The novelty of the study resides on the fact that it has collected data from a set of countries not often investigated in a similar context and that it focuses on the effectiveness, feasibility, and implications of incremental approaches. Also, it takes a multidisciplinary approach, by integrating knowledge and expertise from various fields such as climatology, ecology, economics, sociology, and engineering. Moreover, the study explores the co-benefits and trade-offs associated with incremental adaptation measures.

It contributes to the literature to the extent that it emphasises the importance of adaptive management strategies that allow for continuous learning and adjustment and shows the need for context-specific adaptation solutions that consider local socio-economic conditions, ecological characteristics, and vulnerability to climate change impacts.

4. Results and discussion

This section outlines the main findings from the study and focuses on three main areas: types of climate change responses, the characterisation of transformative adaptation actions and challenges to transformative adaptation, as well as the limitations of incremental adaptation implementation.

4.1. Types of climate change responses

A total of 20 country cases were selected, which are composed of coastal, interior and islands regions. There are, in total, 57 sub-units among the selected country cases (Fig. 4). A number of them are situated in South Asia, including India. India is one of the world's countries most affected by climate change, whereby large-scale severe floods and droughts are among the main climate change impacts (Eckstein et al., 2021). In Africa, Zimbabwe and Kenya were among the African countries most affected by climate change in 2019 (Eckstein et al., 2021). Both are severely threatened by natural hazards such as droughts (often leading to desertification) caused by drastic rainfall decreases, which undermine their water security and food security.

The overall case studies cover a large geographical area and diversity in cultural, ecological, social-ecological and socio-environmental systems, governance and political frameworks. Transformative adaptation dynamics are synergistic with participatory processes, multi-institutional and multi-level collaborative practices, governance with the involvement of stakeholders and decision-makers, knowledge-sharing, climate literacy and capacity for innovation (Fedele et al., 2019; Mapfumo et al., 2017).

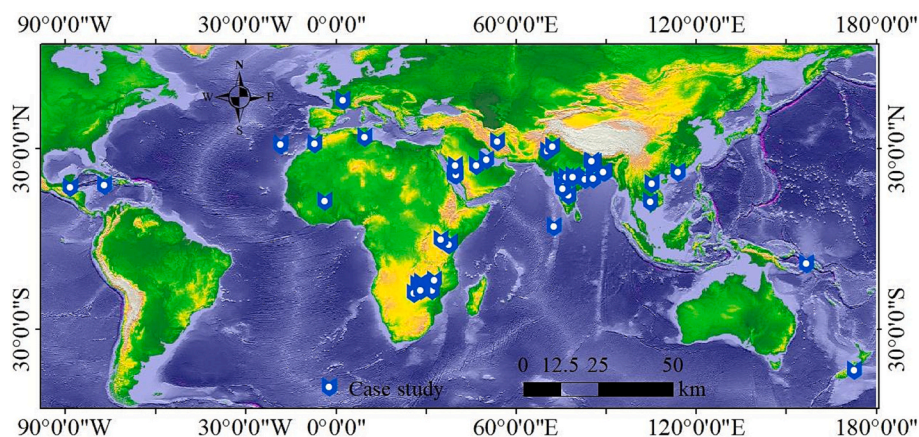


Fig. 3. Map plotting the countries used in the case studies.

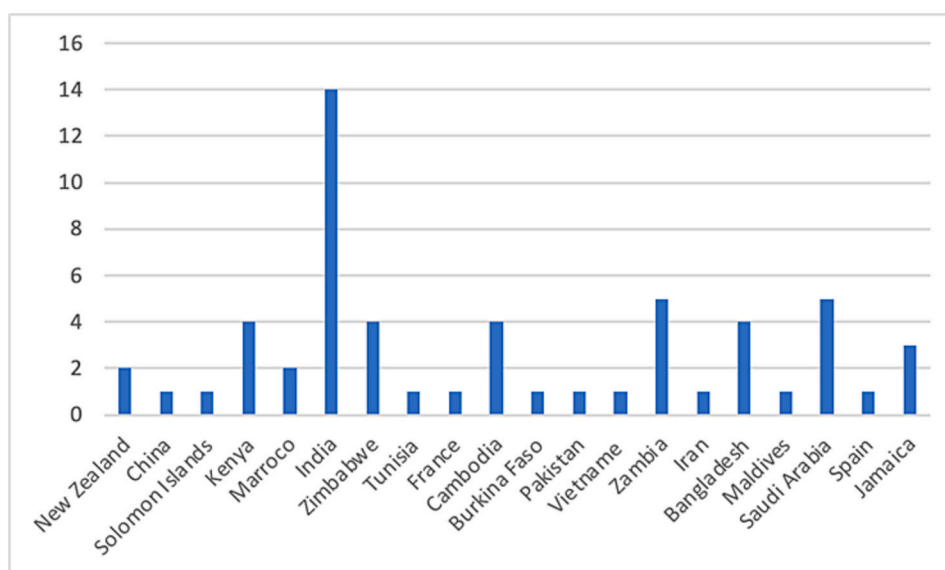


Fig. 4. Number of sub-units for the case analysis by countries.

However, there is a need for these efforts to combine the impacts of incremental and transformative adaptation measures. The number of interventions targeting transformative options are still reduced and are believed to be among other factors limited by the financial capacity of some countries.

The existence of many climate change hazards could justify more bold measures, such as transformational and transformative adaptation. It is important to point out that adaptation options have not been linear or directly proportional to the climate impacts, their magnitude, or their frequency (Brooks et al., 2005; Burns & Machado, 2017). If this would be so, countries such as Bangladesh, India, Zimbabwe, Solomon Islands and Pakistan would be at the forefront.

Table 1 presents the distribution of some types of hazards in the 20 sampled countries that were selected for the case studies and the types of responses seen. Six particular countries (Cambodia, Kenya, Maldives, Morocco, Pakistan, and Tunisia) have implemented and strengthened incremental adaptation measures (i.e., measures aimed at increasing resilience) while China, India, Zimbabwe, Bangladesh and Saudi Arabia have moved towards combined adaptation measures (incremental and transformational, i.e., measures to increase resilience and also reduce vulnerability). Participants from only four (4) countries - New Zealand, Saudi Arabia, France and Spain - have stated that they have introduced transformative adaptation measures, i.e., measures to reduce the root

causes of vulnerability to climate change by moving away from unsustainable trajectories. These countries have also adopted combined options from transformational and transformative adaptation approaches. In Africa, respondents from Zimbabwe, Burkina Faso and Zambia have mentioned that they pursue transformational adaptation measures. Fourteen countries among the country cases are concentrated on and directing efforts towards transformational adaptation (Table 1).

4.2. Characterisation of transformative adaptation actions

According to Table 2, transformative measures have been strongly favoured in sustaining community livelihoods among the selected countries for the case studies. About 50 % of them implement transformative adaptation measures aimed at community livelihoods.

Measures focused on poverty reduction in relation to climate change have been concentrated in Zambia, Iran, Burkina Faso, Bangladesh and Spain, while innovative measures seem to be limited to New Zealand, Cambodia, Spain and Jamaica.

There is a trend among African countries to promote the maintenance of community livelihoods, while Asian countries are directing their efforts to fostering environmental sustainability.

Regarding characteristics of transformative adaptation, about 90 % of the countries are based on building resilience, while 10 % are based

Table 1

Distribution of types of climate change responses to hazards – Incremental (I), Transformational (TI), Transformative (Tv) - by countries in the case studies.

Country	Prevalent climate change hazards	Climate change response		
		I	TI	Tv
Bangladesh	Cyclone, saline intrusion and severe storms	X	X	
Burkina Faso	Extreme climate events and unreliable rainfalls		X	
Cambodia	Heat, water-stress and droughts	X		
China	Severe typhoon	X	X	
France	Drought and heat	X		X
India	Severe droughts and flood	X	X	
Iran	Extreme temperature changes and droughts		X	
Jamaica	Intense and unpredictable rainfall and droughts		X	
Kenya	Desertification	X		
Maldives	Sea level rise, saline intrusion and water shortage stress	X		
Morocco	Water stress and droughts	X		
New Zealand			X	X
Pakistan	Severe flood, high temperature, water stress	X		
Saudi Arabia	Temperature	X	X	X
Solomon Islands	Tropical cyclones and El Niño		X	
Spain	Heavy winds, intense rainfall and droughts		X	X
Tunisia	Drought and heat	X		
Vietnam	Storms, floods, heat waves, droughts		X	
Zambia	Severe rainfall decrease		X	
Zimbabwe	Severe droughts	X	X	

on creative, innovative changes in norms and beliefs. Forty percent of these countries (New Zealand, Kenya, Cambodia, Pakistani, Vietnam, Bangladesh, Spain and Jamaica) have focused on resilience building and strengthening adaptation measures and how they may cause transformative changes.

Overall, the results obtained illustrate the importance of a wider debate on transformation, in relation to adaptation to climate change. The case studies serve the purpose of deepening our understanding of the role of global transitive efforts and paths towards transformative adaptation.

4.3. Challenges to transformative adaptation and limitations of incremental adaptation implementation

The study identified various types of challenges for implementing transformative adaptation. About 50 % of the sampled countries are challenged by limited financial resources. The other problems experienced are:

1. Limited government support
2. Lack of political will
3. Lack of cooperation and engagement of the key partners
4. Weak institutions
5. Limited understanding of extreme climate events and their impacts.

All African countries face similar problems, and the lack of financial resources and lack of political will are the main challenges among them. In addition to limited financial resources, many Asian countries face problems such as lack of cooperation, engagement and in-depth knowledge of climate events as the main challenges. This scenario is in line with recent research on this theme (e.g., Fedele et al., 2019).

Concerning incremental adaptation, we found that limitations are different between countries. Nevertheless, we found that financial constraint is the main limitation in about 30 % of the countries. Yet we also found that: 1. absence of training and education, 2. limited scales of project implementation, 3. limited infrastructure and technologies, and 4. political and partner engagement are the main limitations of 60 % of the countries.

Table 2

Characterisation of transformative adaptation across the sampled countries for the case studies.

Country	Transformative adaptation	Characterisation
Bangladesh	Poverty reduction, upkeeping community livelihoods and sustainability	Resilience building, and change in norms and beliefs
Burkina Faso	Upkeeping community livelihood and poverty reduction	Resilience building
Cambodia	Innovative, building sustainable and resilient community livelihoods	Creative and innovative, resilience building and change in norms and beliefs
China	Fostering environmental and education sustainability	Resilience building
France	Fostering environmental sustainability	Resilience building
India	Upkeeping community livelihood	Resilience building
Iran	Upkeeping livelihoods, poverty reduction and forestry sustainability	Resilience building
Jamaica	Innovative, livelihoods community, fostering sustainability	Creative and innovative, and resilience building
Kenya	Innovative and upkeeping community livelihoods	Resilience building and change in norms and beliefs
Maldives	Upkeeping community livelihood	Resilience building
Morocco	Fostering environmental sustainability	Resilience building
New Zealand	Upkeeping community livelihood and innovative	Creative and innovative, resilience building and change in norms and beliefs
Pakistan	Fostering environmental sustainability	Creative and innovative, and change in norms and beliefs
Saudi Arabia	Fostering environmental sustainability	Resilience building
Solomon Islands	Fostering environmental sustainability and upkeeping women livelihoods	Resilience building
Spain	Innovative, poverty reduction and fostering sustainability	Creative and innovative, and change in norms and beliefs
Tunisia	Fostering environmental sustainability	Resilience building
Vietnam	Fostering environmental sustainability	Resilience building, and change in norms and beliefs
Zambia	Poverty reduction	Resilience building
Zimbabwe	Upkeeping community livelihood	Resilience building

Table 3

Countries' limitations on incremental adaptation and challenges to transformative adaptation.

Country	Limitations of incremental adaptation	Barriers to transformative adaptation
Bangladesh	Ineffective protection of livelihoods, assets and food security, and short-term adaptation	Lack of capital, risks of salinity, stagnation, lack of government initiatives
Burkina Faso	Limited affordability towards climate change adaptation measures	Lack of stakeholder engagement, and limited climate awareness
Cambodia	Illegal logging and mining, corruption, and lack of political will	Lack of political will, financial constraints, and limited community engagement
China	Lack of comprehensive measures and disaster recovery caused by a severe typhoon	Limited cooperation and stakeholder engagement
France	Low impact and limited scale of adoption by individuals	Limited government aid and investment
India	Financial constraints, stakeholder engagement	Synchronisation and lack of cooperation
Iran	Institutional components, low participation of youth, and lack of education	Limited governmental aid and educational courses for farmers
Jamaica	Lack of community training, and financial constraints	Funding inaccessibility, limited government aid, and lack of investments
Kenya	Sand barriers inadequacy and financial constraints	Limited financial resources and government actions
Maldives	Limited resource provision and education for sustainability	Limited financial resources and lack of technological education for women
Morocco	Limited scale of adoption by individual	Financial constraints, lack of political will, and oil sector's legal inflexibility
New Zealand	Financial constraints, inflexibility of stakeholders and language barriers	Financial constraints, lack of political will and lack of cooperation
Pakistan	Limited focus on small landholders and limited farmer engagement	Weak institutions and limited ownership of government
Saudi Arabia	Limited responses and poorly designed infrastructure	Delays in implementing the construction of the drainage channels, and limited water availability
Solomon Islands	Infrastructure adjacent to the ocean	Limited understanding of extreme events
Spain	Financial constraints, and limited technological expert support	High levels of gender inequality, limited leadership, limited community engagement
Tunisia	Limited scale of adoption by individuals	Limited government aids and investment
Vietnam	Costly, farmers cannot afford to adapt, maladaptation, and lack of provision of long-term benefits	Limited awareness raising and capacity development
Zambia	Spatial and resource limitations to extend adaptation services	Limited NGO and government aids, lack of scientific knowledge
Zimbabwe	Lack of investments and financial support	Macroeconomic environment constraints

Respondents in each case were also asked to report on barriers or limitations to the implementation of transformative adaptation, which are summarised in [Table 3](#).

These responses are consistent with the findings from [Fedele et al. \(2019\)](#), who stated that the lack of political support, together with financial constraints, infrastructure and available competencies, pose limitations to transformative adaptation. There are two limitations to this study. One is the coverage of the selected countries. Countries from North America and South America are not included. However, there are selected countries that have similar socioeconomic and geographical contexts to the two continents. Moreover, as stated above, the Asian and African countries are part of the most affected countries by climate change. In addition, these countries are expected to be hotspots of population growth in the coming decades ([UN DESA, 2022](#)), thereby increasing the expected number of vulnerable people. Two is the bias in the number of subunits in each country. For instance, India has more subunits than China.

5. Conclusions

There is a consensus among scholars that global climate change is one of the greatest threats to poor and marginalised communities. Under current climate change conditions, both incremental and transformative adaptations are needed in order to reduce climate-induced poverty and social inequalities. The difference between incremental and transformative adaptations lies in the scope and scale of the adaptation measures. We broadly consider that incremental adaptation can only induce changes in the socio-ecological system, often without significant change to the basic system structure. In contrast, transformative adaptation is a set of measures that challenge the structural root causes of vulnerability and adaptive capacity ([Few et al., 2017](#)). It leads to new arrangements, fundamentally different from the previous context, and to irreversible shifts of societal change. Both incremental and transformative adaptations require careful identification of a portfolio of possible options to avoid maladaptation practices. The results obtained confirm the hypothesis that developing countries' pursuit of incremental

adaptation is hindered by various limitations other than financial constraints.

Our findings highlight the context-specific nature of the challenges related to the implementation of incremental adaptation. Since this type of adaptation strategy tries to adjust to the complexity of the pre-existent institutions and socio-political systems in place, the challenges it deals with has to be specific, therefore, to the context in which it is implemented. There is no one-fits-all view at play here, and a deep understanding of institutional mechanisms and historical and socio-political contexts is critical to design measures that are better suited to changing conditions.

There are more generic challenges for transformative adaptation. Even though a number of adaptation measures are developed to address climate change challenges and stimulate a transformation, many of these initiatives lack a systematic implementation strategy. The research shows that implementation agents are not always aware of the content of the portfolio of adaptation measures, as they are not involved in the formulation processes. Moreover, the climate change policy process was designed to engage stakeholders from both the national and sub-national scales. But in practice, the inclusion in the process does not always start from the bottom nor is centred on community needs and aspirations ([Dupuis & Biesbroek, 2013](#); [Füssel, 2007](#)). In most countries, adaptation measures and policies are designed for people, not with them. It is evident that systemic change or significant shift to new arrangements cannot happen under such circumstances.

Lack of funding is another major barrier to transformative adaptation. The financial support required by countries to enhance the resilience of communities and enable transformation is not always available, and it affects their operational capacity. The situation is even more complex with the ongoing decentralisation process, where the responsibility of collecting the financial support is handled by the local authorities. Given the magnitude of the task and the requirement of funds, national funding support is critical for the support of climate-related initiatives. Addressing these problems is important, so as to pave the way for more sustainable climate change adaptation.

CRediT authorship contribution statement

Conceptualization: WLF; Data curation: All authors; Formal analysis: ALS, UA, Funding acquisition: WLF; Investigation: All authors; Methodology: WLF, ALS, ALB, AS; Project administration: YA; Resources: WLF; Supervision: WLF; Validation: UM, OMA, AN, JG, CL, ET; Visualization: YA, ALS, PP, DC; Roles/Writing - original draft: All authors; Writing - review & editing: All authors.

Declaration of competing interest

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

Data availability

Data will be made available on request.

Acknowledgment

This study was funded by the International Climate Change Information and Research Programme (ICCIRP) and is part of the “100 Papers to Accelerate Climate Change Mitigation and Adaptation” Initiative.

References

- Aguilar, F. C., Bentz, J., Silva, J. M., Fonseca, A. L., Swart, R., Santos, F. D., & Penha-Lopes, G. (2018). Adaptation to climate change at local level in Europe: An overview. *Environmental Science & Policy*, 86, 38–63.
- Aina, Y. A., Wafer, A., Ahmed, F., & Alshuwaikhat, H. M. (2019). Top-down sustainable urban development? Urban governance transformation in Saudi Arabia. *Cities*, 90, 272–281.
- Barnett, J., & O'Neill, S. (2010). Maladaptation. *Global Environmental Change*, 20, 211–213.
- Brink, E., & Wamsler, C. (2019). Citizen engagement in climate adaptation surveyed: The role of values, worldviews, gender and place. *Journal of Cleaner Production*, 209, 1342–1353.
- Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change*, 15, 151–163.
- Burch, S., Shaw, A., Dale, A., & Robinson, J. (2014). Triggering transformative change: A development path approach to climate change response in communities. *Climate Policy*, 14(4), 467–487. <https://doi.org/10.1080/14693062.2014.876342>
- Burns, T. R., & Machado, N. (2017). Disaster risk reduction and climate change adaptation - A sustainable development systems perspective. *Sustainability*, 9(2), 293. <https://doi.org/10.3390/su9020293>
- Carter, R., Ferdinand, T., & Chan, C. (2018). *Transforming agriculture for climate resilience: A framework for systemic change*. Washington DC, US: World Resources Institute.
- Catrien, J. A. M., Termeer, A. D., & Biesbroek, G. R. (2017). Transformational change: Governance interventions for climate change adaptation from a continuous change perspective. *Journal of Environmental Planning and Management*, 60(4), 558–576. <https://doi.org/10.1080/09640568.2016.1168288>
- Clarke, D., Murphy, C., & Lorenzoni, I. (2018). Place attachment, disruption and transformative adaptation. *Journal of Environmental Psychology*, 55(2018), 81–89.
- Colloff, M. J., Martin-Lopez, B., Lavorel, S., Locatelli, B., Gorrdard, R., Longaretti, P. Y., ... Murphys, H. T. (2017). An integrative research framework for enabling transformative adaptation. *Environmental Science & Policy*, 68(2017), 87–96.
- Commission on Climate Change and Development (CCCCD). (2009). *Closing the gaps: Disaster risk reduction and adaptation to climate change in developing countries*. Stockholm, Sweden: Ministry of Foreign Affairs.
- Dupuis, J., & Biesbroek, R. (2013). Comparing apples and oranges: The dependent variable problem in comparing and evaluating climate change adaptation policies. *Global Environmental Change*, 23(6), 1476–1487. <https://doi.org/10.1016/j.gloenvcha.2013.07.022>
- Eckstein, D., Künzel, V., & Schäfer, L. (2021). *Global climate risk index 2021: Who suffers most from extreme weather events? Weather-related loss events in 2019 and 2000–2019*. Bonn, Germany: Germanwatch.
- Eriksen, S., Aldunce, P., Bahinipati, C. S., D'Almeida Martins, R., Molefe, J. I., Nhemachena, C., ... Ulsrud, K. (2011). When not every response to climate change is a good one: Identifying principles for sustainable adaptation. *Climate and Development*, 3(2011), 7–20. <https://doi.org/10.3763/cdev.2010.0060>
- Eriksen, S., & Brown, K. (2011). Sustainable adaptation to climate change. *Climate and Development*, 3(1), 3–6. <https://doi.org/10.3763/cdev.2010.0064>
- Eriksen, S., & Lind, J. (2009). Adaptation as a political process: Adjusting to drought and conflict in Kenya's drylands. *Environmental Management*, 43(5), 817–835. <https://doi.org/10.1007/s00267-008-9189-0>
- Eriksen, S., & O'Brien, K. L. (2007). Vulnerability, poverty and the need for sustainable adaptation measures. *Climate Policy*, 7(4), 337–352. <https://doi.org/10.1080/14693062.2007.9685660>
- European Union. (2014). *Adaptation to climate change*. <https://doi.org/10.2834/849380>. Available at: https://ec.europa.eu/clima/sites/clima/files/docs/factsheet_adaptation_2014_en.pdf (last accessed 30/01/2019).
- Fedele, G., Donatti, C. I., Harvey, C. A., Hannah, L., & Hole, D. G. (2019). Transformative adaptation to climate change for sustainable social-ecological systems. *Environmental Science & Policy*, 101, 116–125.
- Few, R., Morchain, D., Spear, D., Mensah, A., & Bendapudi, R. (2017). Transformation, adaptation and development: Relating concepts to practice. *Palgrave Communications*, 3, 17092. <https://doi.org/10.1057/palcomms.2017.92>
- Füssel, H. M. (2007). Adaptation planning for climate change: Concepts, assessment approaches, and key lessons. *Sustainability Science*, 2(2), 265–275.
- Ghahramani, A., & Bowran, D. (2018). Transformative and systemic climate change adaptations in mixed crop-livestock farming systems. *Agricultural Systems*, 164(July 2018), 236–251. <https://doi.org/10.1016/j.agsy.2018.04.011>
- Ghahramani, A., & Moore, A. D. (2015). Systemic adaptations to climate change in southern Australian grasslands and livestock: Production, profitability, methane emission and ecosystem function. *Agricultural Systems*, 133(2015), 158–166. <https://doi.org/10.1016/j.agsy.2014.11.003>
- Ghahramani, A., & Moore, A. D. (2016). Impact of climate changes on existing crop-livestock farming systems. *Agricultural Systems*, 146(2016), 142–155. <https://doi.org/10.1016/j.agsy.2016.05.011>
- Harper, C. (2016). *Opinion: Why cities are the future for farming*. National Geographic (October, 2016).
- Healey, M., & Healey, R. L. (2016). How to conduct a literature search. In *Key methods in geography* (p. 44). SAGE Publications Ltd.
- Hess, J. J., Mallilay, J. N., & Parkinson, A. J. (2008). Climate change: The importance of place. *American Journal of Preventive Medicine*, 35(5), 468–478.
- Hölscher, K., Frantzeskaki, N., & Loorbach, D. (2019). Steering transformations under climate change: Capacities for transformative climate governance and the case of Rotterdam, the Netherlands. *Regional Environmental Change*, 19(2019), 791–805. <https://doi.org/10.1007/s10113-018-1329-3>
- Huq, S. (2017). Transformative adaptation to climate change. Politics of Climate Change. The Daily Star. Available at: <https://www.thedailystar.net/opinion/politics-climate-change/transformative-adaptation-climate-change-1383313> (last accessed 30/01/2019).
- IPCC. (2018). Global warming of 1.5°C. In V. Asson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, ... T. Waterfield (Eds.), *Special report*. Available at: <https://www.ipcc.ch/sr15/> (last accessed 31/01/2019).
- Kates, R. W., Travis, W. R., & Wilbanks, T. J. (2012). Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, 109(19), 7156–7161. <https://doi.org/10.1073/pnas.1115521109>
- Konnolla, T., & Unruh, G. (2008). Really changing the course: The limitations of environmental management systems for innovation. *Business Strategy and the Environment*, 17, 411–419. <https://doi.org/10.1002/bse.487>
- Korhonen, J., & Seager, T. (2008). Beyond eco-efficiency: A resilience perspective. *Business Strategy and the Environment*, 17(7), 411–419. <https://doi.org/10.1002/bse.635>
- Leal Filho, W., Balogun, A. L., Olayide, O. E., Azeiteiro, U. M., Ayal, D. Y., Muñoz, P. D. C., ... Li, C. (2019). Assessing the impacts of climate change in cities and their adaptive capacity: Towards transformative approaches to climate change adaptation and poverty reduction in urban areas in a set of developing countries. *Science of the Total Environment*, 692, 1175–1190.
- Lesk, C., Rowhani, P., & Ramankutty, N. (2016). Influence of extreme weather disasters on global crop production. *Nature*, 529(2016), 84–87. <https://doi.org/10.1038/nature16467>
- Lonsdale, K., Pringle, P., & Turner, B. (2015). *Transformative adaptation: What it is, why it matters & what is needed*. In *UK climate impacts programme*. Oxford, UK: University of Oxford.
- Mapfumo, P., Onyango, M., Honkonpon, S. K., El Mzouri, E. H., Githeko, A., Rabeharisoa, L., ... Agrawal, A. (2017). Pathways to transformational change in the face of climate impacts: An analytical framework. *Climate and Development*, 9(5), 439–451.
- Marshall, N. A., Crimp, S., Curnock, M., Greenhill, M., Kuehne, G., Leviston, Z., & Ouzman, J. (2016). Some primary producers are more likely to transform their agricultural practices in response to climate change than others. *Agriculture, Ecosystems and Environment*, 222(2016), 38–47.
- Mechler, R., & Schinko, T. (2016). Identifying the policy space for climate loss and damage. *Science*, 354(6310), 290–292.
- Morita, T., Nakicenovic, N., & Robinson, J. (2000). Overview of mitigation scenarios for global climate stabilization based on new IPCC emission scenarios (SRES). *Environmental Economics and Policy Studies*, 3(2), 65–88.
- Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences*, 107(51), 22026–22031. <https://doi.org/10.1073/pnas.1007887107>
- Mustelin, J., & Handmer, J. (2013). Triggering transformation: Managing resilience or invoking real change?. In *Proceedings of transformation in a changing climate conference, 19–21 June 2013*. Norway: University of Oslo.
- Pelling, M., & Dill, K. (2010). Disaster politics: Tipping points for change in the adaptation of sociopolitical regimes. *Progress in Human Geography*, 34(1), 21–37. <https://doi.org/10.1177/0309132509105004>
- Pelling, M., O'Brien, K., & Matyas, D. (2015). Adaptation and transformation. *Climatic Change*, 133(1), 113–127. <https://doi.org/10.1007/s10584-014-1303-0>

- Perez-Catala, A. (2014). Conceptualizing transformational adaptation. Available from <http://climate-exchange.org/2014/03/02/conceptualizing-transformationaladaptation/>.
- Revi, A., Satterthwaite, D., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R. B., Pelling, M., ... Sverdlík, A. (2014). Towards transformative adaptation in cities: The IPCC's Fifth Assessment. *Environment and Urbanization*, 26(1), 11–28.
- Rickards, L., & Howden, S. M. (2012). Transformational adaptation: Agriculture and climate change. *Crop & Pasture Science*, 63(3), 240–250. <https://doi.org/10.1071/CP111172>
- Rippke, U., et al. (2016). Timescales of transformational climate change adaptation in sub-Saharan African agriculture. *Nature Climate Change*, 6(6), 605–609. <https://doi.org/10.1038/nclimate2947>
- Robinson, J., Bradley, M., Busby, P., Connor, D., Murray, A., Sampson, B., & Soper, W. (2006). Climate change and sustainable development: Realizing the opportunity. *Ambio*, 35(1), 2–8.
- Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. *Foresight*, 3(1), 15–31. <https://doi.org/10.1108/14636680110803003>
- Shi, L. (2019). Promise and paradox of metropolitan regional climate adaptation. *Environmental Science & Policy*, 92, 262–274.
- Shi, L., Chu, E., Anguelovski, I., Aylett, A., Debats, J., Goh, K., ... Roberts, J. T. (2016). Roadmap towards justice in urban climate adaptation research. *Nature Climate Change*, 6(2), 131.
- Smith, J. B. (1997). Setting priorities for adapting to climate change. *Global Environmental Change*, 7(3), 251–264. [https://doi.org/10.1016/S0959-3780\(97\)00001-0](https://doi.org/10.1016/S0959-3780(97)00001-0)
- Solecki, W., Pelling, M., & Garschagen, M. (2017). Transitions between risk management regimes in cities. *Ecology and Society*, 22(2), 38. <https://doi.org/10.5751/es-09102-220238>
- Swart, R., Robinson, J., & Cohen, S. (2003). Climate change and sustainable development: Expanding the options. *Climate Policy, Special Issue on Climate Change and Sustainable Development*, 3(Suppl. 1), S19–S40.
- Thornton, T., & Manasfi, N. (2010). Adaptation genuine and spurious – Demystifying adaptation processes in relation to climate change. *Environment and Society: Advances in Research*, 1(1), 132–155. <https://doi.org/10.3167/ares.2010.010107>
- UN DESA. (2022). *World population prospects 2022: Summary of results*. UN DESA/POP/2022/TR/NO. 3.
- Vermeulen, S. J., Challinor, A. J., Thornton, P. K., Campbell, B. M., Eriyagama, N., Vervoort, J. M., Kinyangi, J., Jarvis, A., Laderach, P., Ramirez-Villegas, J., Nicklin, K. J., Hawkins, E., & Smith, D. R. (2013). Addressing uncertainty in adaptation planning for agriculture. *Proceedings of the National Academy of Sciences*, 110(21), 8357–8362. <https://doi.org/10.1073/pnas.1219441110>
- Warner, B. P., & Kuzdas, C. P. (2017). The role of political economy in framing and producing transformative adaptation. *Current Opinion in Environmental Sustainability*, 29, 69–74.
- Warner, K., Zommers, Z., Wreford, A., Hurlbert, M., Viner, D., Scantlan, J., ... Tamang, C. (2019). Characteristics of transformational adaptation in climate-land-society interactions. *Sustainability*, 11(2)(356), 1–22. <https://doi.org/10.3390/su11020356>
- Wise, R. M., Fazey, I., Smith, M. S., Park, S. E., Eakin, H. C., Van Garderen, E. A., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, 28, 325–336.
- World Resources Institute. (2019). Transformative adaptation. Available at: <http://www.wri.org/our-work/project/transformative-adaptation>.
- Yin, R. K. (2003). *Case study research, design and methods* (3rd ed.). Newbury Park: Sage Publications.