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ORIGINAL ARTICLE

Climate Resilient Development Pathways in Global Drylands

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Abstract
The Intergovernmental Panel on Climate Change (IPCC) Working Group II Report on Adaptation, Impacts and Vulnerability identifies the urgent need to embark upon Climate Resilient Development Pathways. Climate Resilient Development acknowledges that adaptation needs to be undertaken together with mitigation and development, in joined-up, inclusive, just and equitable ways, across multiple arenas of engagement. In highly vulnerable systems with complex development contexts, such as drylands, where globally, warming is already exceeding that of humid areas, urgent action is vital, as the window of opportunity for Climate Resilient Development is rapidly closing. This paper considers challenges and opportunities in charting Climate Resilient Development Pathways in the world's drylands. It highlights the importance of stakeholder engagement and partnership building to harness diverse knowledge sources, situating equity and justice concerns at the core of decision making and actions such as land restoration. It notes that while technological solutions offer potential to advance Climate Resilient Development, they need to be developed in an inclusive manner and used in ways that do not undermine Indigenous knowledge and local knowledge or exacerbate inequalities. Many of the challenges to Climate Resilient Development go beyond technology to include highly contextual differences in understanding, environment, institutions and access to finance. Adequate assessment of trade-offs in Climate Resilient Development actions in drylands remains vital to the framing of Climate Resilient Development Pathways for different groups. The paper concludes by identifying major urgent research gaps considering upscaling, stakeholder responsibilities and governance, the magnitude of investment that is necessary, and the need for appropriate monitoring, evaluation and learning.

Keywords Adaptation · Mitigation · Climate change · Sustainability · Equity · Trade-offs

1 Introduction

The Summary for Policymakers of the IPCC Working Group 2 report on adaptation, impacts, vulnerability (IPCC 2022) was approved by governments on the last day of February 2022. The report involved 270 authors from 67 countries, working over the period 2017–2022 to assess more than 34,000 peer-reviewed journal papers. The headline findings provide a stark wake up call, not least because the need for climate action is highlighted as being more urgent than previously assessed. The world needs to embark upon Climate Resilient Development Pathways: development trajectories that integrate adaptation, mitigation and sustainable development to advance towards high resilience and low risk futures to secure a liveable future for all this decade, to have the greatest likelihood of keeping global average temperature rise to below 1.5 °C, as well as avoiding getting locked into long-term pathways toward less sustainable futures. These urgent climate actions are vital if other policy aspirations

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such as the Sustainable Development Goals (SDGs) are to be met. To achieve Climate Resilient Development at a global scale requires the design and navigation of diverse Climate Resilient Development Pathways at smaller scales, with different pathways being appropriate in different social–ecological systems, including different climate-sensitive environments, such as mountains, drylands, small islands and polar regions. This paper examines some of the major findings in the IPCC report and highlights some of the contextual challenges and opportunities in determining Climate Resilient Development Pathways in drylands.

2 Climate Change and Development in the Drylands

Dryland areas are the hyper-arid, arid, semi-arid and dry sub-humid areas of the planet that cover about 45–47% of the Earth's land area (Koutroulis 2019), and are inhabited by around a third of the world's population: c.3 billion people (van der Esch et al. 2017). In some drylands, for example in Africa, human populations are projected to double by 2050 (IPCC 2019). These systems provide a multitude of ecosystem services that are globally valuable, as well as hosting unique biodiversity and a rich geological and cultural heritage, including extensive Indigenous and local knowledge (Mirzabaev et al. 2022), and are a key source of energy and building materials, labour and agricultural produce for expanding urban areas. Drylands offer a complex setting for action from both environmental and developmental perspectives, even before climate change impacts are superimposed. Substantial numbers of dryland inhabitants live in poverty; mostly, but not solely, in the developing world. Everyday challenges include water scarcity, land degradation, hunger, malnutrition and poor health, while inadequate governance in some dryland areas has led to economic and political marginalisation and exacerbated conflict and displacement (Stringer et al. 2017). A wide variety of traditional and emerging responses to climate-related water scarcity across these areas typify the challenges of living in drylands (Leal Filho et al. 2022), while viable alternatives to natural resource-based livelihoods are largely lacking. This combination of dry conditions and high rainfall variability, rich Indigenous knowledge but also pervasive conditions of socio-political marginalisation frame both the urgency of achieving Climate Resilient Development outcomes as well as the dimensions that enable Climate Resilient Development in drylands.

The four key dimensions enabling Climate Resilient Development as identified in the IPCC report (panel a, Fig. 1)—ecosystem stewardship, equity and justice, inclusion, and knowledge diversity—manifest differently in different contexts. The dimensions describe the quality of interactions between diverse actors required for societal choices and associated actions to be made that support Climate Resilient Development. Ecosystem stewardship refers to the nature of environment–society relations that pervade knowledges and decisions. In drylands, water availability is a key aspect of such relations. Water availability is threatened under a changing climate, despite increasing calls for Integrated Water Resources Management (Stringer et al. 2021). Dryland systems are highly sensitive to changes in precipitation and potential evapotranspiration, and surface warming of 1.2–1.3 °C over global drylands during the period 1920–2015 has exceeded the 0.8–1.0 °C warming over humid lands (Mirzabaev et al. 2022). Observed climate trends in deserts and semi-arid areas have already affected biodiversity, soils, nutrient cycling (including the carbon cycle) and water resources. Six percent of the global dryland area experienced desertification over the period 1982–2015, due to a combination of unsustainable land use and land management practices, and climate change (Mirzabaev et al. 2022). Degradation of ecosystems, including those in drylands, not only increases greenhouse gas emissions but also erodes adaptation and livelihood options, sometimes irreversibly.

Equity and justice in interactions transcend scales from the global to the local. The current context of drylands means many barriers need to be overcome to build adaptive capacity (Mirzabaev et al. 2019). At the same time, dryland populations in developing nations are some of the world's lowest carbon emitters, so these groups disproportionately bear the burden of climate impacts resulting from historical and current emissions elsewhere (Trisos et al. 2022). Several chapters in the IPCC report highlight this unjust and inequitable situation, noting also that women, youth, elderly, ethnic and religious minorities, Indigenous People and refugees are often most vulnerable (Birkmann et al. 2022; Trisos et al. 2022). These groups sit at the intersection of poverty and inequality but have least voice and agency, particularly in those drylands where issues of gender equity and marginalisation are inadequately addressed in governance processes and institutions (Birkmann et al. 2022). For example, drought and water insecurity disproportionately affect women and girls in drylands as they are traditionally responsible for collecting water, often from distant sources (Graham et al. 2016). In spending more time and energy travelling further to meet household water needs, they are left with less time for education and income-generating activities, and may be more exposed to violence and less able to relocate as an adaptation option (Mirzabaev et al. 2022; Sommer et al. 2015). Furthermore, differential agricultural productivity between men and women is about 20–30% or more in dryland regions of Ethiopia and Nigeria (Ghanem 2011). Trisos et al. (2022) highlight the disproportionate impact on children when adverse climatic conditions can

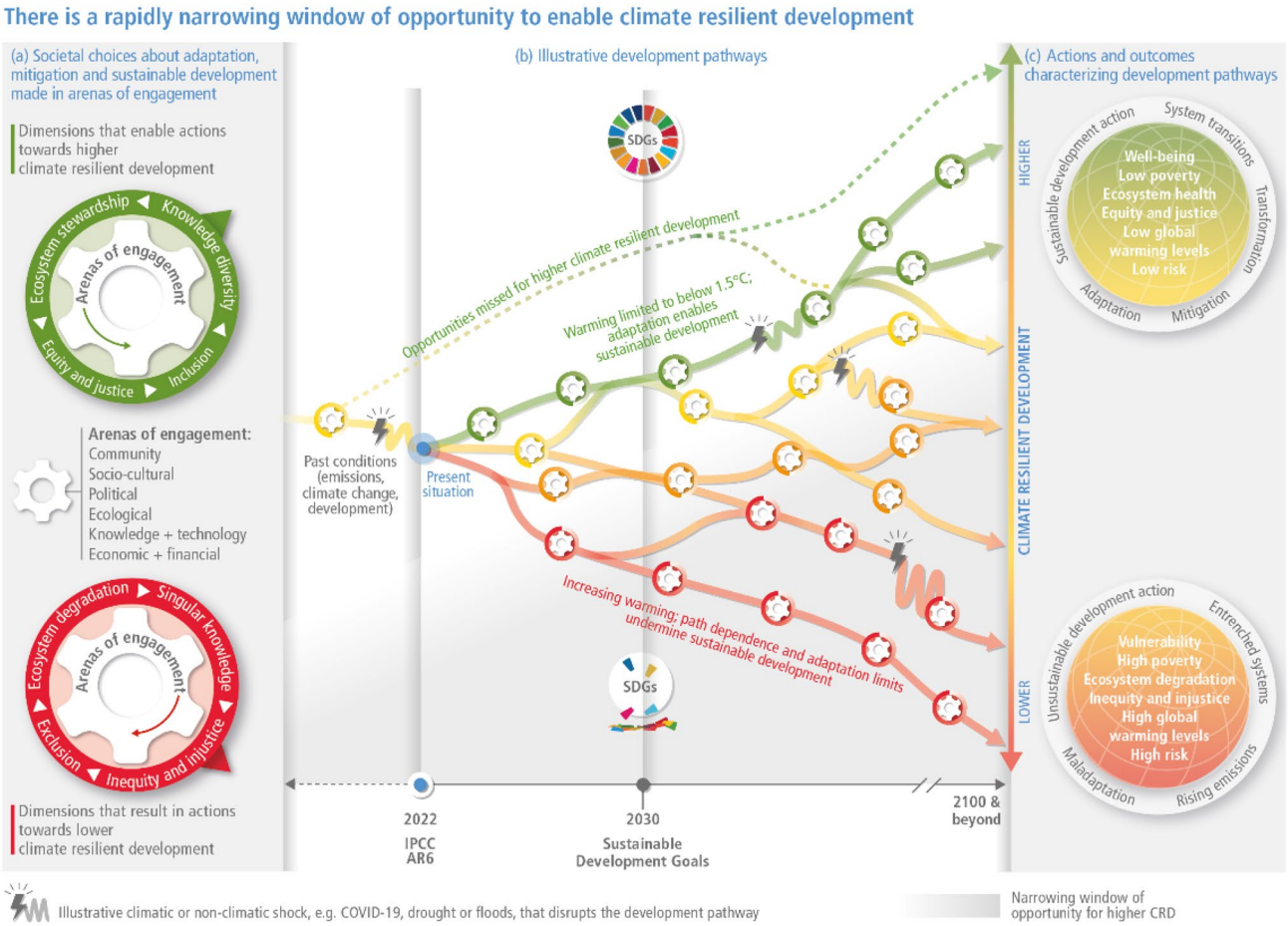

Fig. 1 Climate resilient development pathways (source: IPCC 2022, Summary for Policy Makers). Climate Resilient Development (CRD) is the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development. This figure builds on Figure SPM.9 in AR5 WGII (depicting climate resilient pathways) by describing how CRD pathways are the result of cumulative societal choices and actions within multiple arenas. **a** Societal choices towards higher CRD (green cog) or lower CRD (red cog) result from interacting decisions and actions by diverse government, private sector and civil society actors, in the context of climate risks, adaptation limits and development gaps. These actors engage with adaptation, mitigation and development actions in political, economic and financial, ecological, socio-cultural, knowledge and technology, and community arenas from local to international levels. Opportunities for Climate Resilient Development are not equitably distributed around the world. **b** Cumulatively, societal choices, which are made continuously, shift global development pathways towards higher (green) or lower (red) Climate Resilient Development. Past conditions (past emissions, climate change and development) have already eliminated some development pathways towards higher CRD (dashed green line). **c** Higher CRD is characterised by outcomes that advance sustainable development for all. Climate Resilient Development is progressively harder to achieve with global warming levels beyond 1.5 °C. Inadequate progress towards the Sustainable Development Goals (SDGs) by 2030 reduces Climate Resilient Development prospects. There is a narrowing window of opportunity to shift pathways towards more Climate Resilient Development futures as reflected by the adaptation limits and increasing climate risks, considering the remaining carbon budgets

reduce income among farming households, leading parents to pull children out of school (Marchetta et al. 2019; Randell and Gray 2016), or where poor harvests from droughts or supply interruptions from extreme weather events lead to undernutrition among young children, negatively affecting cognitive development and schooling potential (Alderman et al. 2006). In West and Central Africa, experiencing lower-than-average rainfall during early life is associated with up to 1.8 fewer years of completed schooling in adolescence (Randell and Gray 2016, 2019). In Malawi, in utero drought exposure has been associated with delayed school entry among boys (Abiona 2017), while in rural Zimbabwe, experiencing drought conditions during the first few years of life was associated with fewer grades of completed schooling in adolescence, which translates into a 14% reduction in lifetime earnings (Alderman et al. 2006). While international policy has recognised the differentiated and compounding nature of the challenge for women and children (Okpara et al. 2019), substantial progress to rectify the situation remains to be seen.

Equity and justice are closely linked both to inclusion in processes and the recognition and mobilization of diverse knowledges in decision-making. The importance of historical power structures (including colonialism) in shaping current vulnerabilities (Birkmann et al. 2022; Trisos et al. 2022), as well as the varied starting points for action within and between different systems (Stringer et al. 2020) are heavily underscored within the IPCC report. Opportunities for Climate Resilient Development are not equitably distributed (Schipper et al. 2022). Even within a single dryland system there is substantial diversity. For example, rural agricultural and natural resource dependent livelihoods are presented with very different challenges to and opportunities for Climate Resilient Development compared to the livelihoods of people living in dryland megacities in complex, diversified economies, such as Cairo, Tehran, Beijing, Mexico City and Los Angeles (Stringer et al. 2021). Climate change literacy is generally lower in rural dryland areas of Africa potentially driving reactive or uninformed coping responses to climate shocks and stressors within these regions, where people do not have understanding of human-caused climate change (Simpson et al. 2021). Climate Resilient Development that integrates adaptation, mitigation and development in the drylands needs to tackle these multiple challenges through the societal transformations that ensue, while also negotiating an inevitable diversity of complex trade-offs that operate across different temporal, spatial and social scales.

3 Climate Resilient Development Pathways in the Drylands

The pathways framing presented by the IPCC report, which charts possible ways forward for Climate Resilient Development, encompasses the central dimensions, linkages and feedbacks, processes and behaviours of different systems. It provides a useful approach to consider the interaction between diverse actions as well as sequencing of these actions over time, allowing identification of risks of possible path dependencies and lock-ins (Haasnoot et al. 2013; Lade et al. 2020). The IPCC report explains that higher or lower Climate Resilient Development will occur as a result of the societal choices made and the pathways that are taken, with the higher Climate Resilient Development pathways slipping out of reach if we fail, within the next decade, to shift to development that limits warming to below 1.5 °C globally while accelerating forms of adaptation that advance sustainable development (Fig. 1; IPCC (2022); Schipper et al. (2022)).

Pathways themselves are diverse, interlinked across particular temporal and spatial scales, and laden with differential power, interests and priorities, which in turn affect how (and by whom) they are framed. Pathways that move drylands towards higher Climate Resilient Development facilitate futures with greater levels of wellbeing, healthy ecosystems, equity and justice, alongside lower levels of poverty, global warming and risk (panel c, Fig. 1). Conversely, pathways that lead towards lower Climate Resilient Development deliver vulnerability, widespread poverty, ecosystem degradation, inequity and injustice, high global warming levels and high risk (Schipper et al. 2022). Cumulatively the set of diverse decisions make up societal choices that can potentially reorient the drylands towards higher Climate Resilient Development by supporting deep system transitions (IPCC 2022). These choices involve transformative adaptation, mitigation and sustainable development actions that drive five interdependent systems transitions (energy, land and other ecosystems, urban and infrastructure, industrial and societal transitions). For example, land and water use in one system, such as energy, impacts the other systems, including land and ecosystems. Transformative change, including changes to underlying values, worldviews, ideologies, structures and power relationships, in addition to practices and technologies, are required to achieve systems transitions and advance Climate Resilient Development. These transitions must not only target the climate change challenge, ensuring successful adaptation and reduced emissions, but also address the development needs of dryland systems, and be implemented with the necessary urgency so as not to jeopardise achievement of the SDGs. This must be done in a joined-up, integrated way.

Societal choices are made about adaptation, mitigation and development actions in political, economic and financial, ecological, socio-cultural, knowledge and technology, and community arenas from local to international levels (Schipper et al. 2022). The messy bricolage of decisions and outcomes that emerge means that it can be difficult to tell whether choices made are supporting resilience or not, and whether all the inevitable trade-offs are equitably addressed in such a way that adequately reflects societal values, local priorities and Indigenous and local knowledge. One way to help address this and catalyse the necessary collective shifts in attitudes, values, consciousness and behaviours is to ensure space for engagement of all legitimate dryland stakeholders, including governments, the private sector and civil society, supported by adequate monitoring, evaluation and learning. Core principles of justice in terms of recognition, participation and distribution need also be delivered, as equity and sustainability are inseparable in the quest for climate resilient, sustainable and fair futures (Leach et al. 2018).

Governance for Climate Resilient Development in dryland Africa includes long-term planning, all-of-government approaches, transboundary cooperation and benefit-sharing, development pathways that increase adaptation, including development of robust legislative frameworks

that develop or amend laws to mainstream climate change into their empowerment and planning provisions (Trisos et al. 2022). Without cross-sectoral, transboundary and long-term planning, adaptation and mitigation response options in one sector can become response risks in other dryland and non-dryland areas, exacerbating impacts across multiple sectors and space which can lead to maladaptation. For example, maintaining indigenous forest benefits biodiversity and reduces greenhouse gas emissions, but afforestation—or wrongly targeting ancient grasslands and savannas in Africa's drylands for afforestation or reforestation—harms water security and biodiversity, and can increase carbon losses as a result of fire and drought (Nuñez et al. 2021; Trisos et al. 2022; Wigley et al. 2020).

Stakeholder engagement and partnership building can help to bring diverse sources of knowledge to the charting of Climate Resilient Development Pathways, incorporating findings from scientific research, Indigenous knowledge and local knowledge, as well as practical know-how. In drylands, natural resource users are recognised to possess vast practical knowledge that has developed and evolved over generations, particularly in terms of locally appropriate land management and adaptations used by groups, such as pastoralists (Benjaminsen et al. 2012). However, this knowledge is not always sufficiently harnessed to inform local policies and decision making. Similarly, many traditional practices are being marginalised due to the introduction of more modern processes, materials and technologies, which can offer some advantages but also introduce new risks, vulnerabilities and exacerbate inequalities (Birkmann et al. 2022). Mitigation concerns can also be overlooked, with new technologies sometimes increasing local emissions.

Core to Climate Resilient Development is the close interconnectedness between the humans and the environment, as reflected in the key dimensions of societal choices advancing such development, including ecosystem stewardship, equity and justice, inclusion and knowledge diversity. This socio-natural interconnectedness is illustrated by how ecosystems, including drylands, offer significant untapped potential, not only to reduce climate risks, and deal with the causes of climate change, but also to improve lives and livelihoods and advance towards the SDGs, for example through the restoration and enhancement of ecosystem services. Although many drylands are degraded, such 'nature-based solutions' can present opportunities for Climate Resilient Development if approached appropriately (Wells et al. 2021)—involving the necessary groups, ensuring equity, and following proper assessment and mitigation of trade-offs. It is nevertheless important that the potential for restoration is not viewed as a green light for degrading activities to continue, as this perpetuates the view that the problem can be remediated later. The rapidly closing window of opportunity to embark on Climate Resilient Development Pathways means waiting to act is no longer an option.

Existing policy frameworks offer options for an integrative approach but need to move beyond the rebranding of long-standing land degradation and desertification discourses that delegitimise local adaptation strategies in the name of environmental restoration. The IPCC report challenges popular dryland policy actions, such as sedentarisation of mobile pastoralists and land privatisation, leading to exclusion and inequity (Mirzabaev et al. 2022) and notes that restoration needs to be undertaken in ways that support achievement of higher levels of Climate Resilient Development. Restoration actions also need to be combined with those that tackle the drivers of dryland degradation and desertification, following the land degradation neutrality (LDN) response hierarchy, to prevent > reduce > reverse degradation (Cowie et al. 2018). At a global level, more than 125 countries, particularly in drylands, have established LDN targets (Mirzabaev et al. 2022). Yet, achievement of LDN demands all aspects of an enabling environment to be addressed, including inclusive policies, regulations and enforcement, sustainable institutions, timely and accessible finance and effective knowledge-sharing (Verburg et al. 2019) in conjunction with transparent, inclusive and replicable decision processes to prioritise areas that are targeted for investment (Dallimer and Stringer 2018). While restoration actions have been shown to support adaptation and provide alternative livelihoods (Lengefeld et al. 2022), there is still a need to increase off-farm incomes in many drylands, introducing new value chains and less climate-sensitive alternative livelihoods. For example, smallholder farmers in African drylands are diversifying their income sources to offset reduced yields or crop losses by shifting labour resources to off-farm work, or by migrating seasonally or longer term (Hove and Gweme 2018; Kangalawe 2017). Off-farm activities provide financial resources that rural households need to cope with extreme climate variability (Hamed et al. 2018; Rouabhi et al. 2019). However, in many cases, these off-farm activities can be maladaptive at larger scales, such as when households turn to charcoal production, which contributes to deforestation and thus carbon emissions (Egeru 2016), or when migration leads to increased vulnerability or aggravates the work burden faced by women (Poudel et al. 2020; Rao et al. 2019). Diversification also represents a transformation of livelihoods that in itself can lead to exclusion and poverty dynamics. Similarly, the scale of dryland restoration matters, illustrating a fine line between adaptation and maladaptation. Evaluations of large-scale ecological restoration programmes in China's drylands found that while regreening goals were achieved, restoration through tree planting imposed substantial pressure on water resources, the full effects of which are not yet fully known (Li et al. 2021). Reforestation and afforestation

programmes in drylands require full impact assessments to be carried out given concerns for water availability and wider impacts on biodiversity and ecosystem services (Bond et al. 2019; Veldman et al. 2015) to ensure mitigation does not undermine adaptation and development and lead towards lower levels of Climate Resilient Development.

Considering whose knowledge frames what counts as restoration is also important in determining if such actions can contribute to, or undermine, Climate Resilient Development. The IPCC report highlights the importance of recognising diverse knowledges, including Indigenous knowledge and local knowledge, to understand and adapt to climate change in ways that shift inequitable relations (Mustonen et al. 2022). Recent unpublished research in dryland northern Nigeria examined the potential for indigenous non-irrigated trees to support new value chains and business opportunities for rural women through partnerships between researchers, NGOs, farmers and policymakers (Favretto et al. 2022). Land users had previously felled trees on their land to increase the cultivable area. However, in most cases farmers had not removed the stumps. Training land users (particularly women) on how to care for the stumps and revive them supported climate change mitigation goals, and enabled adaptation and development as trees recovered, while new business models were created following local processing of non-timber tree products. Focus on non-irrigated indigenous species meant that no additional demand was placed on tree nurseries for seedlings, no increased pressures were placed on water sources, and emissions were lower than those associated with planting new trees as the stumps were already in situ.

4 Research Gaps

Upscaling local successes like those in dryland northern Nigeria in moving toward Climate Resilient Development in the drylands remains a challenge (Thomas et al. 2018) and is an important topic for further research. Alongside this, knowledge gaps remain as to what specific actions are needed, where and by whom, to support system transformations, and how costs and benefits can be balanced over appropriate and acceptable time frames, particularly given the urgency to act now. Increasing levels of warming narrow the options and choices that are available and feasible (Schipper et al. 2022). Climate research finance on Africa has not targeted countries, where drylands make up a significant proportion of their territory leading to severe knowledge gaps, in part determined by colonial and Anglophone patterns of knowledge creation (Overland et al. 2021; Simpson et al. 2022).

While business as usual is taking us towards increasing economic and non-economic costs, and inaction is exacerbating the challenge, there are currently no reliable estimates of the magnitude of investments needed to ensure we are embarking on Climate Resilient Development pathways. For example, estimates of annual finance flows targeting adaptation for Africa are billions of USD below the lowest adaptation cost estimates for near-term climate change and finance has not targeted the most vulnerable countries, ecosystems and human populations (Savvidou et al. 2021; Trisos et al. 2022). At a global level, the adaptation finance gap is widening in terms of funds committed (many of which have not yet materialised) compared to the increasing costs of adaptation and what is required. Questions of who should pay and how much need urgent resolution, particularly when historical emissions and the unequal distribution of impacts are considered. These issues are particularly pertinent in view of the global SDG aspiration to 'leave no one behind'.

Finally, robust approaches for monitoring, evaluation and learning are needed, to assess our progress along Climate Resilient Development Pathways in the drylands. This includes the need to consider all relevant sectors, stakeholders and time frames, and to put in place mitigation measures such that trade-offs do not exacerbate inequality and injustice, as well as harnessing synergies and co-benefits to support both human and ecological wellbeing. If warming can be limited to 1.5 °C, the magnitude of climate risks that need to be adapted to can be reduced and the chances of a sustainable future for all, including those in the drylands, are increased.

5 Conclusions

The recent IPCC report highlighted the urgent need to embark on Climate Resilient Development Pathways and that climate action that includes fundamental system transformations needs to begin this decade. This commentary has set out some of the challenges and opportunities for dryland systems to move toward higher levels of Climate Resilient Development. Inclusivity and equity need to be at the heart of actions to reduce emissions, adapt effectively and improve human livelihoods and wellbeing. All stakeholders at all levels, drawing on all kinds of knowledge, need to engage across all arenas (political, economic and financial, ecological, socio-cultural, knowledge and technology, and community) if Climate Resilient Development and the SDGs are to be achieved.

Data Availability No primary data are used in this paper; therefore, there are no data sets to be made available.

Declarations

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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