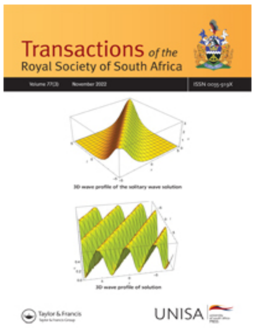

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Brief Report

The value of researching the past for crafting sustainable African mountain futures

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THE CHALLENGE PRESENTED BY MOUNTAINS

Mountains are among Africa's most dramatic landscapes. Comprising 20% of the continental surface area (Nsemgiyumva, 2019; Platts *et al*., 2011), mountains are vital to the lives of the 1.1 billion people across Africa who depend either directly or indirectly on the many benefits that they provide. For the over 250 million people that live on mountains in Africa (FAO, 2015) this dependency is direct: montane environments are particularly attractive areas due to their high diversity of natural resources and biodiversity (Capitani *et al*., 2019b), high agricultural productivity, reliable water supply, cooler climate (Ashagre *et al*., 2018; Cormier-Salem *et al*., 2018), and supply of fuel. Mountains supply ecosystem services on which the continent relies, not least as all major rivers have headwaters in the highlands. Mountains largely determine Africa's sustainable development potential by underpinning food production, energy security, biocultural diversity and tourism income, and they supply timber and non-timber forest products (Capitani *et al*., 2019b; Green *et al*., 2018; Cuni-Sanchez *et al*., 2021). Additionally, highland areas will be the focus of afforestation projects, important for current carbon emission targets (see Glasgow Leaders' Declaration on Forests and Land Use 2021). As a result, highlands are the focus of many ecosystem "restoration" initiatives aiming to both sequester carbon and conserve biodiversity, and they are where historical degradation has been acute (Marchant 2021). Whilst recent studies of reforestation potential focus on ecological viability (Bastin *et al*., 2019; Brancalion *et al*., 2019), the feasibility of such projects under local and regional socio-economic settings and their impacts on local communities and biodiversity have yet to be adequately assessed. Understanding such socio-economic settings and impacts on communities is important for achieving the laudable aims of the "Bonn Challenge" of "restoring" 350 million ha of forest by 2030, while Africa100 aims to "restore" 100 million ha by 2030. Alongside this, in 2019 the United Nations (UN) launched the "Decade on Ecosystem Restoration" (2021–2030), aiming to massively scale up the restoration of degraded and destroyed ecosystems as a measure for communities to mitigate and adapt to the increasing frequency and magnitude of climate extremes (Platts *et al*., 2015; Lange *et al*., 2020; Adler *et al*., 2021), and to enhance food and water security and biodiversity (UN, 2021).

Large parts of Africa nevertheless faces unique problems, with the highest rate of population growth globally (Molotoks *et al*., 2021) and the highest poverty gap index (Molotoks *et al*., 2021), increasing pressure on both water supplies (Ashagre *et al*., 2018) and ecosystems (Marchant, 2021). This is combined with rapidly changing climates, transformation of models of socio-economic development, intensification of competing land uses, and often contradicting, ineffective national and international policies working at cross-cutting purposes, all threatening the future sustainability and resilience of mountain social-ecological systems (MtSES) (Archer *et al*., 2018; IPBES, 2019; Thorn *et al*., 2021a, 2021b). There is growing evidence that the rate of warming increases with elevation, with mountains experiencing more rapid changes in temperature than lowland regions or the global average (Pepin *et al*., 2015; Thorn *et al*., 2020). However, setting appropriate restoration goals requires detailed information on former and current climates, forest extent, ecosystem composition and structure, and the heterogeneity of MtSES landscapes. Without such information we cannot assess the true impact of initiatives such as afforestation on biodiversity or its effect on other ecosystem services.

The disruption of historically predictable seasons, including droughts and floods, has major implications for crop yields and livestock, and hence for the livelihoods of pastoralists, farmers and other small-scale producers (Kariuki *et al*., 2018, 2021). The recent Intergovernmental Panel on Climate Change (IPCC) 6th Assessment report (AR6) (Adler *et al*., 2021) illustrated how East African snow and glaciers have significantly decreased in recent decades – with high confidence that this trend will continue over the twenty-first century (Adler, 2021). Consequent decreases in runoff will have downstream impacts, such as for people in the Pangani River Basin (Hejnowicz *et al*., 2022). Although the challenges lie in the future, we have no opportunity to change the past and its

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multiple wrongs – from colonial rule and the ensuing division of land and communities and social political systems, through to the industrial removal of key ecosystem engineers such as elephants and importing new crops like maize that have transformed landscapes (Finch *et al*., 2016). For instance, Tanzania lost 60% of its elephants between 2009 and 2015 (numbers dropped from 109,051 to 43,330), while in Mozambique during the same period the country lost 48% of its elephant population (Down to Earth, 2015).

RESEARCHING THE PAST

Palaeoecological and archaeological syntheses covering past years of entangled environmental and human histories of Africa's mountains can be used to define the varied social-ecological dynamics and legacies of this biocultural heritage (Marchant *et al*., 2018). Due to their high environmental and climatic sensitivity, mountains offer useful high-resolution sites of reconstruction of palaeoecological change and drivers of change. These data can be combined with historical and observational studies of the political ecology of environmental and climatic change over the last several decades – including multi-proxy analyses to understand short- and long-term periodicities that characterise the East African region. For instance, Olago and Odada (2001) studied the palaeoecology of East African mountains, given their unique context straddling the equator, experiencing north–south hemispheric climatic influences, and influenced by the surrounding ocean, linking high latitudes and tropics. Evidence derived from several swamps and small lakes across a range of altitudes on Mt Kenya document that the interactions between changing climate, settlement histories and use of the mountain resources are complex and characterised by high degrees of uncertainty. Understanding the drivers and implications of the co-evolution between people and the environment in MtSES thus demands new thinking, exploring cross-scalar connections, new analytical tools and novel combinations of expertise if we are to envisage and pursue sustainable, equitable future pathways. More long-term records of change are required to assess the significance of historically documented and modern-day change in sub-Saharan Africa. For instance, the mechanisms underlying the abrupt, large-scale climatic events in the Holocene occurred during a period with similar climatic conditions to those today. In Kenya, for instance, the upper boundary of the Montane Forest Belt in Mount Elgon has lowered, reducing the altitudinal range of the forest species. Similarly, today we are seeing significant changes on Mount Kenya: there are significant amounts of C4 grasses at altitudes up to 3200 m, and some select C4 grasses (e.g., *Androppgon amethustinus*) are found up 4000 m. Understanding changes in the past can help us better understand current-day variability and potential future change (Hamilton, 1972; Odada *et al*., 2020).

Previous work provides clear examples of using combined past, present and future perspectives (Gillson and Marchant, 2014; Marchant and Lane, 2014; Odada *et al*., 2020), and how this connects to our understanding of biogeography (Ahrends *et al*., 2011), land-use modelling (Capitani *et al*., 2016; Kariuki *et al*., 2018, 2021) and remote sensing (Pfeifer *et al*., 2014, 2018; Ahrends *et al*., 2021). These perspectives can be brought together to underpin transdisciplinary work on co-producing knowledge to model social-ecological systems and evaluating adaptation pathways using participatory scenarios (Capitani *et al*., 2019a; Thorn, 2019; Thorn *et al*., 2020). Long-term information is urgently required on the potential of forests and other vegetation types to sequester and store carbon, particularly where many of the previously extensive montane forests of Africa have been converted to agricultural land (Burgess *et al*., 2007). The former palaeoecological extent of some of these forests indicates that some 80–90% of the forest cover has been lost (Willcock *et al*., 2016). Protection and restoration of indigenous grasslands and shrublands (e.g., Bond, 2016) against the rapidly moving afforestation front has to be informed by a thorough understanding of the evolution of landscape mosaics in relation to human land use. While we can see the impact of relatively recent (decadal) land-cover changes through LandSat, Sentinel and other satellite-based Earth observation products, a deeper perspective is essential to enable realistic restoration and management plans that are within the historical range of variability of the system, hence building resilience and adaptive capacity (Mora *et al*., 2013). A blanket focus on reforestation and carbon storage, for example, without consideration of landscape history, may threaten biodiversity or key ecosystem services, such as crop or livestock production and water provision, especially if the restoration of an indigenous forest is not distinguished from afforestation with alien species that might alter soil and hydrology and lead to conflict with downstream users, while simultaneously eroding the cultural and symbolic value of trees for local inhabitants (von Hellermann, 2016).

The focus on carbon sequestration through forest management raises critical questions around the types of ecosystem services that local people value and use – including provisioning and regulating services as food, water and energy (Villa *et al*., 2014b; Kanter *et al*., 2015). For instance, the French TotalEnergies gas and oil company recently announced intensions to plant 40 000 ha of trees on the Batéké Plateau in the Republic of Congo. However, the location the company has chosen is a rolling mosaic of grasses and wooded savanna with patches of denser forests. While benefits can be derived in terms of sequestering 10 million tonnes of carbon dioxide over 20 years, producing timber and creating jobs, species are being planted in areas where they do not naturally occur – with adverse impacts on the ecology of the area (Einhorn, 2022). Similar arguments are being advocated in the central Drakensberg Mountains of South Africa, where eucalyptus, which consumes large amounts of water and catalyses frequent fires, is being used for reforestation efforts in Afromontane grasslands. A trend is emerging from a historical progression from production-focussed non-native pastures to more diverse suites of native species and habitats in the restoration landscape (Carbutt and Kirkman, 2022). However, benefits are mediated by cultural imperatives such as social memory and a sense of place that, when combined, reflect the importance people assign to nature's contributions (Dasgupta, 2021). While people may drive land-use changes, they also develop core "relational values" such as social identity, responsibility, stewardship towards land, and embodied practices (Chan *et al*., 2016) that shape particular ways of deriving well-being "from," "with," "in," and "as" nature (O'Connor and Kenter, 2019) and inform how they "weather" climate change, potentially over long time frames (Petek and Lane, 2021).

GETTING AHEAD OF THE CHALLENGES

Current crises continue to be dealt with in a reactionary way – be it food aid or water rationing during recurrent droughts, or fences to mitigate human–wildlife conflict and control access to protected areas. A major challenge for MtSES research is thus to identify pathways toward sustainable human development under multiple and interacting drivers of change arising from environmental (e.g., climate and vegetation change), demographic (e.g., population growth and migration), socio-economic (e.g. market integration and foreign investment flows), and cultural (e.g., loss of traditional ecological knowledge) aspects. For instance, the Middle Drâa valley in the Atlas Mountains in Morocco is one of many semi-arid to arid mountainous areas which in the last 50 years has been struggling with increasing water scarcity threatening self-sufficient animal husbandry and consequent food security (Nsengiyumva, 2019). The area has a long history and an indigenous population which has been able to adapt and optimise scarce natural resources, but in the last decade the Zagora region has been among the regions worst affected by desertification – with further impacts on palm groves or oases, salinity, road infrastructure, irrigation networks, and groundwater upstream and downstream. An integrated approach is required in managing the release of the Mansour Addahbi dam to avoid sedimentation and environmental and economic risk; e.g., combining participatory irrigation management, crop diversification, better interaction between farmers and planners, and the use of small tanks (Karmaoui *et al*., 2015).

To address these challenges and confront uncertainty in areas such as the social-economic opportunities mountain ecosystems provide, we need to synergise new fertile niches between, and across, different disciplines, such as between engineers, anthropologists, ecologists, biologists, zoologists, political scientists, social scientists and others. However, this is much more than another call for interdisciplinary science: the holistic science requires a synergy between those already working within interdisciplinary space to apply novel scientific approaches across time. For this integrated approach to happen we must foster non-typical knowledge exchanges between diverse fields and communities in a process of collaborative learning facilitated by innovative exchanges of researchers between institutions – such as through knowledge exchanges, field visits, visiting researcher visits and working together on international collaborative research programmes, and building capacities in both the Global North and South in terms of transdisciplinary practice. This will add value and lead to breakthroughs from a social-ecological perspective through time to explore alternative future scenarios that are *realistically* informed by landscape history and regionally adapted dynamic models, accommodating ecological reality as well as stakeholders' values surrounding nature, while acknowledging socio-economic and cultural complexity. Integration will further allow researchers, policymakers and implementers to get ahead of the challenges rather than continually reacting, from one crisis to the next.

An integrated perspective will allow us to deal with contemporary challenges such as climate and ecosystem change, conservation strategies, biocultural heritage protection and the achievement of nature-based solutions for *inclusive* development in MtSES. Such an integrative approach is critical to modelling pathways to sustainability and will provide a better perspective for the implementation of large-scale targeted initiatives such as Africa100, the UN's decade of restoration and 2022 International Year of Sustainable Mountain Development, and the near-term 2030 Sustainable Development Goal agenda, and to match the far-term (2063) African Union Development Goals.

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