Opinion

# Building ecosystem resilience for climate change adaptation in the Asian highlands

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The Asian Highlands, the vast mountainous area from Pakistan to China including the Hindu-Kush Himalaya and Tibetan Plateau, have considerable global importance; they are the source of most of the major rivers of Asia, which sustain billions of downstream dwellers, are part of four Global Biodiversity Hotspots, and support rich cultural diversity. However, climate warming in the Himalaya–Tibetan Plateau has been greater than two times the global average, and regional climate appears to be shifting with potential to trigger large-scale ecosystem regime shifts ('landscape traps'). A host of other drivers—urbanization/infrastructure development, land-use/agricultural practices, upstream/downstream water management and ongoing nation-state security conflicts—interact with climate signals to produce complex changes across ecological and social systems. In response, highlands people are evolving hybrid forms of adaptive capacity where 'bottom-up' behaviors are mixing with 'top-down' state and market policies. To increase ecosystem and livelihood resilience to future change, there is a need to link upstream and downstream conservation action with local climate adaptation. While the key problem is that institutional and government capacity for coordination is low, we present four general strategies to move forward: application of cross-sector coordinated planning, strategic integration of science-based conservation with developing local-level hybrid knowledge, recognition of the critical role of governance in support of change, and increased emphasis on environmental security. We discuss these strategies for each driver of change in the region. 

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## INTRODUCTION

Into the 21st century as human alteration of Earth's lands and waters continues to expand, less developed regions such as the Asian Highlands are increasingly subject to ecological and social transformation. The highlands, the vast area of mountains and high plateaus above 1000 m stretching from Pakistan to China and including the Hindu-Kush Himalaya and Tibetan Plateau, have considerable global importance; they are the source of most of the major rivers of Asia (Figure 1). This 'Water Tower of Asia' directly sustains approximately 150 million people and has impacts on the lives of several billion downstream dwellers.[1] The Asian Highlands also host parts of four Global Biodiversity Hotspots: the Himalayas, Indo-Burma, Mountains of Southwest China, and Mountains of Central Asia. The region has some of the highest species endemism in the world. In addition, the highlands' great variation in topography and elevation gradients supports rich cultural diversity

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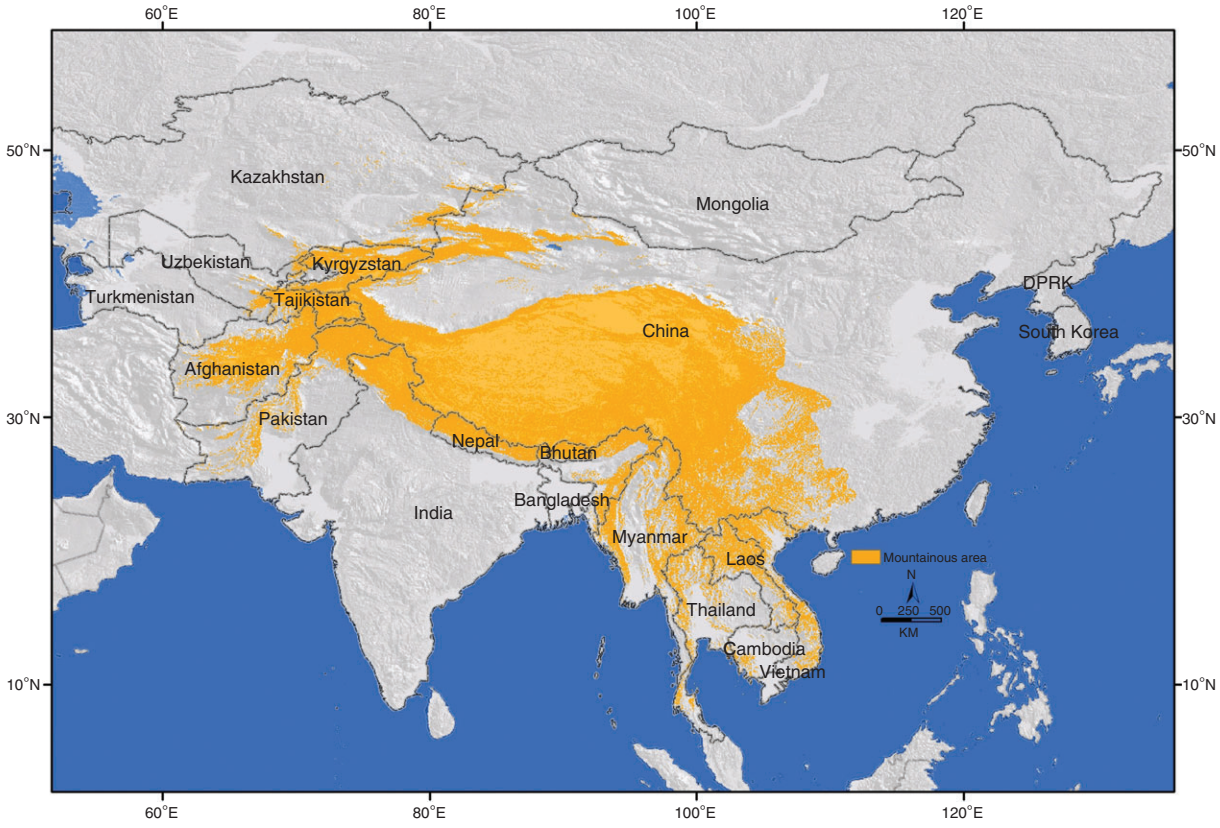


**FIGURE 1 |** Mountains or highlands are steep and high in relation to their surroundings. They include all areas with elevations greater than 2500 m, areas higher than 1500 m with slopes steeper than 2°, and areas of any elevation with slopes of 5° or >300 m above their surroundings, including plateaus and valleys within mountainous terrain. Mountain habitats support living organisms, animals (including humans), and plants, and they cover about 24% of the earth's surface. The 'Asian Highlands', the vast mountainous area including the Tien Shan, Hindu-Kush, Himalaya and Tibetan Plateau, Changbai, and Montane Mainland Southeast Asia (MMSEA), is the source of most of the major rivers of Asia and directly and indirectly sustains approximately 3 billion downstream dwellers.

expressed in multiple languages, land uses and livelihoods.

Much is at stake in the Asian Highlands, yet due to the region's vast scale, extreme topography, ecological diversity and resulting complex climatic conditions, even high-resolution models have yet to yield reliable projections of climate change in the region.[2] There is general agreement from regional studies that temperatures will continue to increase (especially at higher elevations and after mid-century), precipitation will increase but with great variation across the highlands, monsoon precipitation will become more variable in time, space and amount, and extreme events (drought, floods) will become more common.[3,4] Yet. warming in the Qinghai-Tibetan Plateau has already been greater than two times the global average and, depending on location in the region, projections call for warming to increase by 1.5–3°C by 2040–2060 with greater changes by the end of the century.[5] And with some 2/3 of the Plateau underlain by permafrost, rising temperatures have triggered active degradation of this important carbon storage/soil moisture zone.[6] Despite ongoing uncertainty in regard to precise trends, regional climate appears to be in flux and shifting unevenly beyond recent norms.[7] What is less clear are the consequences of these changes for ecosystem composition, structure and function, and the human livelihoods that depend on them. And it is not at all clear that today's conservation actions and government efforts in the Asian Highlands represent an adequate response to these signals.

## THE ASIAN HIGHLANDS IN A WARMING WORLD

The variety of climate impacts that have been observed in the Asian Highlands at multiple scales from species to ecosystems show significant changes in progress. Data show that the growing season on the Tibetan Plateau has already increased by 3 weeks or more,[8] while in high elevation rangelands, rising temperatures are reducing snow cover and changing soil moisture

  

dynamics.[9] These changes will likely have cumulative consequences for both plants and animals that depend on periodically available resources, including seasonal water supplies, pollinator relationships, seed dispersal and more. Along elevation gradients, complex range shifts have been observed for many birds,[10] rhododendron spp.,[11] and snow leopards (*Uncia uncia*).[12] With continued warming, the crop-destroying Tibetan migratory locust (*Locusta migratoria tibetensis*) will likely expand its range northwards and/or westwards along river valleys up onto the Tibetan Plateau.[13]

Given the relatively rapid rate and scale of climate-driven change in the Asian Highlands, the likelihood of regional ecosystem regime shifts or 'landscape traps' is a growing concern. A regime shift may occur when ecosystems shift from one state to another and then stabilize around a new equilibrium.[14] Lindenmayer et al.[15] define 'landscape trap' as a large-scale ecosystem shift into a new state where major functional attributes (i.e., nutrient cycling, water storage, and carbon sequestration) are compromised. These new conditions are then maintained (trapped) as the result of multiple feedbacks between human actions and natural disturbance regimes. Though evidence for landscape traps in the highlands is far from definitive, there are several regions of concern. In the eastern Himalaya, large-scale vegetation shifts have been reported with meadows transforming into shrublands at some of the most rapid rates observed in the world.[16] These changes will likely reduce the capacity of local ecosystems to support pastoral livelihoods based on grazing animals.[17] Data from multiple sites in India show widespread montane plant species distribution changes due to warming temperatures,[18,19] while studies from western Nepal report human outmigration due to temperature-driven loss of ecosystem services that support agricultural livelihoods.[20]There appear to be strong feedbacks between climate impacts and human activities that influence habitat degradation for a range of species and may be leading toward landscape traps. In the eastern Himalaya in China, rising temperatures together with government prohibitions on burning in alpine meadows have facilitated upward movement of treelines.[21] On the eastern edge of the Qinghai-Tibetan Plateau, a potential rangelands regime shift may be developing due to positive feedbacks between altered freezing–thawing processes, permafrost degradation, extreme precipitation events, and overgrazing of livestock. These appear to be contributing to reduced plant cover, increased soil erosion and reductions in populations of the keystone species Plateau pika (*Ochotona curzoniae*).[22] For Asian Highlands rivers, climate-driven impacts coupled with planned dramatic increases in land and water use threaten biodiversity and ecosystem functioning and may contribute to the creation of human-made waterscapes where hydrological and disturbance dynamics are markedly different from before.[23] For example, if plans go forward, Himalayan India will have the highest dam density worldwide with over half of 292 hydropower projects located in what is now dense, relatively undisturbed forest.[24] Across the Asian Highlands, regional climate trends remain far from certain and much will depend on near-term international actions to mitigate carbon emissions. But for an increasing number of landscapes, ecosystem composition, structure, and function are undergoing alterations that appear to be resulting in changes that may provide fewer ecosystem services and less support for traditional peoples' livelihoods.

## INTERACTIVE DRIVERS OF CHANGE IN THE ASIAN HIGHLANDS

But as one can see from the evidence above, climate impacts are not the sole drivers of change in the Asian Highlands nor are they as yet the most important. A host of other drivers interact with climate signals to produce complex regional responses across ecological and social systems. In the highlands, chief among these anthropogenic drivers of change are urbanization/infrastructure development, land-use/agricultural practices, upstream/downstream water management and ongoing nation-state security conflicts. The key is to acknowledge the interactive complexities among these drivers.

At multiple sites in the Himalaya, researchers have discovered that urban population growth and increasing market-based resource consumption in the context of climate change have reduced forest extent and increased the amount of cultivated and degraded lands while general water resources have declined.[25,26] Throughout the Asian Highlands, a shift from subsistence farming toward growing more cash crops for distant markets is well under way. This results from a complex mix of drivers including temperature increases that influence changes in crop selection, improved roads and other infrastructure that provide better market access, and government policy incentives.[27]Though household incomes in many places have increased due to this trend, upland soil loss and runoff from croplands have also grown with unknown downstream effects.[28,29]

Differential social and ecological impacts along elevation gradients add complexity to these interactions. Although data is limited, road building appears to have greater environmental impacts at higher elevations.[30] In Nepal, as mean temperatures increase,

  

low and mid-elevation apple growers are having great difficulties with harvests and are moving away from fruit tree cultivation, while apple farmers at higher elevations have (as yet) few problems.[31] At other locations in Nepal, in mixed maize systems at different elevations, farmers are replacing wheat and millet with vegetables; this is increasing demand for water from irrigation.[32] In Yunnan, China, villagers at sites in close proximity but arrayed along a steep elevation gradient are experiencing different social and climate impacts and are therefore making specific livelihood adjustments depending on their elevation position.[33]

Because of their key role in highlands ecological and human well-being, water resources are of particular concern. Threats to both biodiversity and human water security are increasing in the Asian Highlands.[34] Dams, habitat degradation, road building, pollution and water withdrawals all play a role; the few existing studies that have been performed on these impacts show evidence of increased runoff, reduced groundwater recharge, and depletion of local water resources.[35] Yet, the basics of the water cycle in the region are still being discovered. It was only in 2012, for example, that groundwater was found to contribute six times more than glacial runoff and snowmelt to river discharges[36] and recent research shows previously unknown connections between montane rainfall and evaporation from irrigated agricultural lands at lower elevations.[37] In many river basins, links between altered upstream flows due to dams, roads and agricultural practices and consequences for the densely populated lowlands remain poorly understood.

Overarching all of these is the geopolitics of highlands transboundary water resource management. From Pakistan in the west to China in the east, there are ongoing state-to-state conflicts over water that have so far influenced regional trends more than climate and other drivers of change.[38] With political benefits perceived as outweighing environmental and social costs, most countries have yet to discover that state security may be reduced without better management of transboundary water resources.

Though specific studies remain sparse across this vast region, political, ecological, and social processes in the Asian Highlands are in transition. And as climate change continues, new interactive social drivers of regional change (international REDD + policies, the rising influence of private business over natural resource management and infrastructure development, land tenure changes) may gain influence in the coming years. Given historical political inequities between highland and lowland peoples[39] and the general lack of knowledge of linkages across upstream/downstream gradients and social–ecological systems in the highlands, we can expect more surprises even as our knowledge grows. The question is, in the face of an uncertain future, what can we do to support ecosystem resiliency that maintains and enhances local and regional adaptation to climate and other linked drivers of change?

## STRATEGIES TO SUPPORT ECOSYSTEM RESILIENCE AND CLIMATE CHANGE ADAPTATION

We believe that there are four overarching strategies to support ecosystem resiliency and adaptation to change. The strategies are application of cross-sector coordinated planning, strategic integration of science-based conservation with developing local-level hybrid knowledge, recognition of the critical role of governance in support of change, and increased emphasis on environmental security. None of these strategies have been applied much yet in the Asian Highlands, so, in addition to specific actions, a general scaling-up of these strategies will ultimately be necessary. We spotlight below some applications of these ideas to several of the drivers of change in the Asian Highlands; a detailed treatment addressing all drivers is beyond the scope of this brief opinion paper.

### Cross-Sector Coordination

Whether the focus is urbanization,[40] conservation and land use,[41] agriculture[42] or water management,[43] virtually every study from the Asian Highlands points toward the need for better planning coordination across sectors. Lack of coordinated planning within and between sectors is endemic in the highlands and results from a historical and ongoing low capacity for governance combined with lack of funding. For any given highlands country, a holistic view of planning and local to central government capacity to coordinate such work is a matter of (slow) national development. These efforts can be encouraged by the work of friendly states and international NGOs, but they cannot be funded wholesale. There are also cases where NGO politics hinders rather than helps coordinated planning.[44] Nevertheless, we agree with the strong consensus that coordinated planning is key to adapting to future change and that links between drivers of change must be highlighted in planning analyses. Examples include more focus on connections between urban growth and land use[45] and developing plans that integrate water/food/energy nexus concerns.[46] Of specific interest is developing coordinated planning to address the impacts of potential regime shifts and

  

resulting loss of ecosystem services in the Asian Highlands. Evidence from the USA shows that this will entail cross-sector planning that evaluates trade-offs between natural capital assets and prioritizes costs and benefits using scenarios,[47] actions that so far have not been initiated in the highlands.

Integrated planning, while necessary, is not sufficient. For each specific situation—country, river basin, local watershed—scientists and policymakers must pay particular attention to how to implement plans, given local constraints. The historical trajectory of planning in the highlands has proceeded from national-level neglect of local concerns to top-down outside NGO support to better conceived, but often uncoordinated local pilot projects. The upshot here is that national or NGO-driven plans must be connected better to local implementation realities and also linked strategically to neighboring NGO and government efforts.

## Integrating Science-Based Conservation with Local-Level Hybrid Knowledge

If we have learned one lesson from our work in the Asian Highlands, it is this: nature conservation, ecosystem resiliency and human livelihoods are inextricably linked together. Throughout history, healthy functioning ecosystems have provided the services that bolster humans' ability to respond to change, and in the Asian Highlands both people and nature will be at increasing risk unless more effort is expended on integrating conservation with new developments in how local people are responding to change.

The big picture looks like this. Right now, Asian Highland countries continue to depend on protected areas to conserve biodiversity and critical ecosystem services. But few existing reserves in the highlands were designed for long-term population viability, connectivity with other reserves, integration with adjacent land uses or climate change. Today, as landscape transformations proceed pushed by the overlapping impacts of multiple drivers of change, species are having increasing difficulty navigating up, down, and across, expanding agricultural lands and plantations, dams, and other degraded habitat. At the same time, highland peoples experience both threats and opportunities from climatic and socioeconomic transformations. In response, local people are rearranging their traditional adaptation strategies to include more dependence on outside technology, markets and government support. Despite their poverty, relative lack of political representation and limited education, highlands people are evolving new hybrid forms of adaptive capacity where 'bottom-up' behaviors are mixing with 'top-down' state and market policy in various, location-specific blends.[48] Specific examples (among many) include farmers in the eastern Himalaya in China adapting to climate-driven water stress through a mix of local knowledge (changing planting patterns), market dynamics (switching to commercial crop varieties) and government support (state-funded water storage)[49] and highland villagers in Bhutan[50] and Pakistan[51] employing their traditional knowledge of local conditions while working with government and NGO support to produce community disaster risk reduction plans.

Most of these hybrid efforts are proceeding *ad hoc* and with little connection to science-based conservation. As much as possible, we would like to see conservation actions integrated with local hybrid knowledge while targeting specific drivers of change in the highlands. For example, to address potential regime shifts, land-use and agricultural drivers, we advocate the development of climate-smart landscape linkages in the Asian Highlands. 'Climate-smart' would add in the design principle of optimizing the climate mitigation and adaptation potential for agricultural lands covered in habitat connectivity planning.[52] These linkages could support gene flow, plant and animal range shifts, and the maintenance of the ecological processes that deliver ecosystem services to local people. There are multiple ways to connect landscapes: one can build corridors for species of concern; conserve and restore steeping stone habitats; blend agroforestry tree crops into farmlands and facilitate wildlife movements by building passages under highways and fish ladders over dams.[53] We favor the design approach of Brost and Beier[54] where connectivity is based on land facets—enduring landscape features with uniform topographic and soil characteristics. Land facets would conserve the 'theater' of biological activity, rather than temporary species 'actors' who may be featured in today's ecological 'performance', but, due to climate-induced range shifts, may move tomorrow.

If climate-smart landscape linkages could help to facilitate conservation actions on protected areas, farms and other lands, highland elevation gradients might become climate-smart corridors rather than likely barriers for species range shifts. But there are three major problems with such linkages in the Asian Highlands. First, this type of 'mixed use' conservation planning has been slow to be adopted in the region; Bhutan is the only country to experiment with land facet-based conservation.[55] Second, while there are a few conservation/hybrid knowledge action plans in the highlands, most are focused on blending local, NGO and government approaches to protect forests and do not address agricultural lands. Third, most of

  

the people working on these plans are development experts, poorly educated local people and village officials. Conservation scientists are mostly missing from the mix with the result that there is little science integrated into local planning. We envision an 'ecologized' hybrid knowledge; that is, we would like to see more NGO and government targeted support for blending conservation science incentives into local planning. This would require conservation/development planning teams since few individual researchers are trained to work in both areas. There are some efforts underway in the highlands to combine biological conservation with equity, empowerment, and more local control of natural resources. For example, seven 'Transboundary Landscapes' in Pakistan, Nepal and China have been identified for pilot projects in integrated ecosystem management.[56] However, in part due to political difficulties in building connections between the bottom-up and top-down approaches that are supportive of conserving ecosystem services and human livelihoods, more local and regional government cooperation is needed.

Integration of science-based conservation with local-level hybrid knowledge can also support upstream/downstream water management. A pan-Himalayan study of water infrastructure found that scientific information could help build better local planning and cooperative capacity.[43] Other studies show that, while solutions to water management issues vary across the highlands, there is a common need to link science into community institutions[57] and communicate it more clearly to local people.[58] However, efforts to blend science with local hybrid knowledge are still rare in the Asian Highlands.

## Recognizing the role of governance

A key message for leaders at all levels is that cross-sector coordination and integration of science with local hybrid knowledge are both matters of politics, that is to say, better governance. Recent research from the highlands shows that without more central support for 'bottom-up' adaptation built on blends of ecological and local hybrid knowledge, interactive drivers of change are more likely to undermine ecosystem resilience and social and economic stability.[59]The crux problem at most levels of government is that integrative vision is limited and capacity for coordination remains low. This is true in upstream/downstream governance and management for each specific driver in this paper and we see this everywhere we work—in China, in Nepal and in Pakistan. Experts and NGO staff have their own version of poor integration—they often assume that more research leads to better decision making and are trained to avoid the messy politics surrounding implementation. But pressures from the pace of change are pushing researchers to consider how science may better accommodate social concerns[60] and government leaders to explore questions of natural resource politics more carefully.

We are not sanguine about prospects for rapid political transformation in the Asian Highlands, yet there is mounting evidence that a new focus on governance can help researchers and NGO experts to become more implementation-savvy. For example, in a recent UN report highlighting climate adaptation, eight of eleven recommendations emphasized governance, including integrating local and state responses to change and building better sociopolitical understanding of how risks are perceived and climate adaptation decisions are made.[61] Work from the highlands of China[62] and Nepal[63] shows that local governments appear to be key actors to support resilient adaptation as they are in a position where they can mediate between central authorities' concerns and local community realities.

## Emphasizing Environmental Security

In an Asian Highlands saddled with a history of regional conflicts over resources, recognizing the role of governance cannot be limited to local concerns. There must also be improvement in transboundary management of natural resources. This is especially important for upstream/downstream water management and the future of state security.

Of the nine rivers that course off the Tibetan Plateau, only one is covered by a shared transnational water agreement. The Indus Treaty between Pakistan and India is not perfect, but it has helped adjudicate multiple water conflicts as both countries develop water infrastructure.[64] The rest of the rivers of the highlands are without treaties even as nations actively push for more upstream water withdrawals and hydropower development with little knowledge of downstream cross-border impacts. The Mekong/Lancangjiang[65] and the Brahmaputra/Yarlung Tsangpo[66] are of immediate concern, given the scale of upstream dam building, projected downstream impacts and current political intransigencies.

To help build ecological resilience as they seek to cooperate over water issues, the majority of highland countries have adopted Integrated Water Resource Management. But because this framework does little to address the *politics* of water sharing in a region where politics is paramount, new environmental security analyses may provide a more direct path to solving transboundary challenges. Environmental security

  

examines threats to states posed by environmental trends[67] with a prime benefit being that transboundary resources are considered from the standpoint of how resource sharing can strengthen state stability.[68] When 'security' goes beyond resource management, it can capture the attention of leaders concerned with maintaining stability and power. However, this approach remains theoretical. It has not been used anywhere in the Asian Highlands where the combined impacts of uncoordinated development are just beginning to cause general concern.

## CONCLUSION

From our experience in the Asian Highlands, while countries may be saddled with low capacity for integrated decision making and poor governance that constrains adaptation, we remain optimistic. Although implementation is slow, climate-smart upstream/downstream ecological planning, the evolution of local-level hybrid climate adaptations with a conservation component, and a more savvy focus on the role of governance in decision making are all signals of positive change. This will not be wholesale change—these tools offer limited leverage points with which to nudge governance in the Asian Highlands forward. But if they were better supported by governments and NGOs, the threat of regime shifts and landscape traps might be reduced and local peoples' livelihood actions could more easily evolve toward resilient adaptations.

However valuable these measures might be, they will be difficult to implement in the Asian Highlands. Lack of integration and coordination are products of highland politics, and decision makers often appear satisfied with the *status quo*. It will remain challenging to address climate change when mitigation actions taken now will not likely produce results for decades to come.[69] And though most of the literature (and our experience) is explicit about the need to engage highlands people in order to better understand dynamics between ecosystem changes and social drivers of vulnerability, not all Asian Highlands stakeholders think alike, bear the costs and benefits of change equally, or have equal say in how decisions are made. But given that climate change impacts are projected to intensify, now is the time to experiment with small-scale projects that can assess actions across the highlands' multiple subregions, elevation gradients and livelihood practices. One size does not fit all in this complex landscape—we need to discover what works and what does not work for many local practices *and* political arrangements. Wherever they are implemented along the complex ecological and social gradients of the Asian Highlands, we believe these strategies can assist conservation and development workers to advance support for ecological resiliency and climate change adaptation for people and for nature.

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