The value of a river basin approach in climate adaptation[1]

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Abstract

Climate change is having major impacts on water resources, affecting the quantity, quality and timing of water flows in many places. These changes are likely to increase as climate change advances. Taking a holistic river basin approach to climate adaptation can bring many advantages when building resilience in natural and human systems and addressing conflicts that will increasingly arise as climate change advances. This paper reviews the advantages and challenges of such an approach, drawing on results of a vulnerability assessment and adaptation planning for the Gandaki river basin in Nepal using WWF's 'Flowing Forward' methodology for assessing vulnerability of different human and environmental systems. The paper reviews how the river basin approach frames key adaptation issues and challenges, such as maintaining, provisioning, and regulating ecosystem services; reconciling upstream and downstream needs for water and ecosystem services by various sectors; and maintaining ecological connectivity in order to promote adaptation of freshwater and terrestrial systems and species. Results can be applied in adaptation planning at various levels, including for local communities. The paper also reviews interactions between climate change and development, including changes in land use, hydropower development and water extraction, and examines the value of environmental flow analysis to understand likely combined impacts. Finally, it outlines the importance of multi-sectoral and multi-scale adaptation approaches in river basins, including the need for appropriate institutional structures and policy frameworks.

Key words: river basin, climate change, ecosystem services, hydropower, environmental flow

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Introduction

Changes in climate have caused impacts on natural and human systems around the world in recent decades (Intergovernmental Panel on Climate Change 2014): changing precipitation or melting snow and ice are altering hydrological systems and affecting quality and quantity of water resources; glaciers continue to shrink, affecting runoff and water resources downstream; species range shifts, changing migration patterns, and population changes are manifesting across the world; and crop yields are changing, resulting in more decreases than increases. Impacts from climate-related extremes and associated hazards, such as heat waves, droughts, floods, cyclones and wildfires, reveal significant vulnerability and exposure for both human systems and ecosystems. Climate-related hazards exacerbate other stressors for ecosystems and for livelihoods, especially among people living in poverty.

As climate change advances, its impacts will multiply and become more extreme, with greater impacts on water, agriculture, forestry, energy, transport, settlements, conservation, and health sectors. This paper outlines the value of using river basins as a unit of intervention for building resilience to climate change and climate variability, and promoting adaptation. It draws on the example of the Gandaki river basin in Nepal (Figure 1), where the Hariyo Ban Program[5] used 'Flowing Forward' methodology to assess vulnerability of different human and environmental systems (WWF Nepal 2016a). Designed for large drivers of change at the landscape scale in a data-poor environment, this methodology assesses vulnerability of natural and man-made landscape features through a synthesis of existing background information, peer-reviewed and gray climate science literature, and a participatory stakeholder assessment workshop that includes scenario planning for an uncertain future. The Gandaki assessment was enhanced by information from local level vulnerability assessments and adaptation planning in selected parts of the basin.

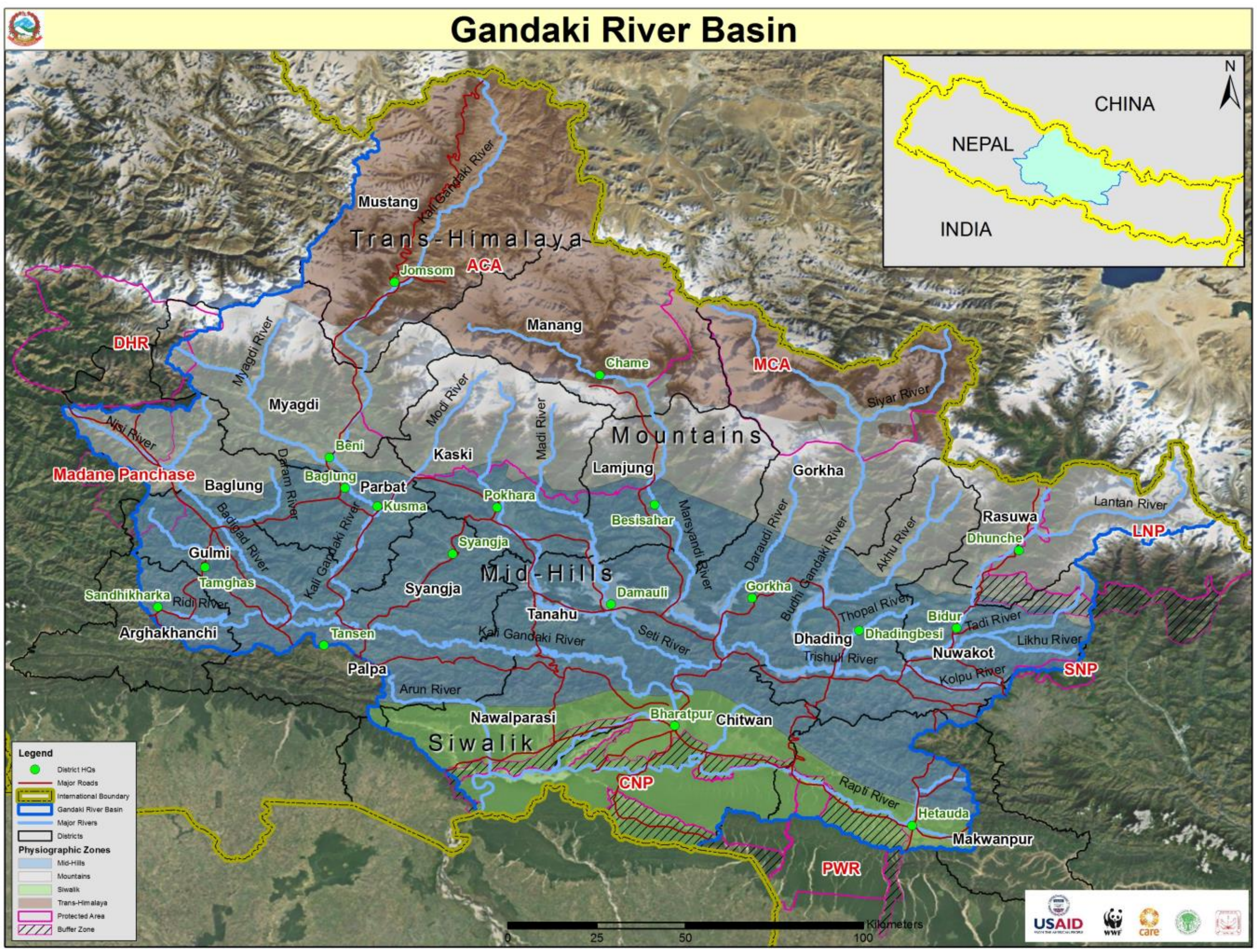
The core principles behind integrated river basin management (IRBM) and integrated water resources management (IWRM) at the heart of the Flowing Forward approach are not new; IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Global Water Partnership 2000). In the face of climate change they have increased urgency and importance as a sound approach for integrated climate adaptation.

The Gandaki basin in Nepal covers 32,057 square kilometers, and encompasses a varied topography from the trans-Himalayan desert and the snowcapped high Himalaya mountains in the north, down through the mid-hills to the Churia (Siwalik) range and the low-lying plains of the Terai in the south. Elevation ranges from 8,091 m at the peak of Annapurna I, the tenth highest mountain in the world, to around 200 meters above sea level in the Terai. A small part of the basin lies in China to the north; the basin drains through the Narayani River in the south to India, where it forms a tributary of the Ganges river. The basin has important water resources, with several

[5] Hariyo Ban (Green Forests) Program is ten-year project funded by USAID that aims to reduce adverse impacts of climate change and threats to biodiversity in Nepal. It is implemented by a consortium of WWF, CARE Nepal, the Federation of Community Forests User Groups Nepal and the National Trust for Nature Conservation

major perennial rivers: Kali Gandaki, Seti, Marsyangdi, Daraundi, Budhi Gandaki, Trishuli, and Rapti. The basin is inhabited by over 4.5 million people of diverse ethnicities. In rural areas people are still heavily dependent upon forests and ecosystem services for their livelihoods and wellbeing; the basin has about 35% forest cover (Ministry of Forests and Soil Conservation 2015). Migration from high altitudes to lowlands, rural to urban areas, and to other countries in search of better livelihood opportunities is common in the region; remittances from employment are the major source of household income (46%). Agriculture, tourism, salaried jobs/services and wage labor are the next largest income sources. Hydropower and other infrastructure are rapidly developing in the basin (WWF Nepal 2013). The eastern part of the basin was seriously affected by the 2015 earthquake whose epicenter was in Barpak in Gorkha district.

Figure 1: The Gandaki river basin in Nepal, showing major rivers and bio-geographical zones



Advantages of taking a holistic river basin approach in light of climate change

Maintaining ecosystem services for people and nature: The most common and serious climate hazards faced by local communities in the Gandaki basin, from over 200 community level vulnerability assessments supported by the Hariyo Ban Program in the basin, are: storms including hail; landslides, floods and droughts; uncontrolled forest fire; and spread of invasive species and diseases (WWF Nepal 2016b). Impacts include declining agricultural production and rising food insecurity; drying of water sources; and increased disaster risk. Vulnerability tends to be very site-specific, especially given the huge range in altitudes and topography, but also due to socio-economic factors including gender, poverty and social exclusion.

As people become more exposed to climate change hazards, ecosystem services can play important roles to buffer their effects: for example, forests can reduce the risk of local flash floods and landslides in the face of more intense localized rainfall and help to maintain dry season water supplies as precipitation patterns become increasingly unpredictable. Functioning floodplains can absorb floodwater and reduce the risk of floods downstream, while also providing critical nutrients for flood dependent vegetation and agriculture (e.g. Secretariat of the Convention on Biological Diversity 2009; Le Quesne 2010). Ecosystems can also act as a safety net for communities when agriculture fails by providing wild foods and other resources, and a place to take temporary shelter from disaster hazards. Hence, restoring or maintaining these ecosystem services can play a major role in adaptation in the face of future uncertainty (e.g. Andrade et al. 2011). This needs to be done holistically and in conjunction with other land uses such as agriculture and industry that often rely on but can also affect the integrity of these services.

Therefore, working at site level is often not enough; interventions may need to be at spatial scales at which ecosystem services operate. For example, bio-engineering to stabilize landslides and river banks downstream may not be effective when land use problems such as increased runoff from upstream deforestation are not tackled. On the other hand, adaptation activities by upstream stakeholders may risk maladaptation if individual communities, countries and sectors take adaptation measures unilaterally without considering possible consequences for ecosystems and other users beyond their immediate jurisdiction: for example, building a dam to boost a town's dwindling water supply can cause wetlands and irrigation canals to dry up downstream.

Hence, building climate resilience often needs to take place at multiple levels and rely on communication, coordination and decision-making among stakeholders. In the Gandaki basin, the Hariyo Ban Program has worked with the Department of Soil Conservation and Watershed Management to facilitate dialogue between upstream and downstream communities in sub-watersheds in collaboration with local stakeholders through support to the implementation of integrated subwatershed management plans, and is collaborating with Government to expand this work to include larger sub-basins and the Gandaki basin itself, with a wider range of stakeholders. River basins represent an ideal scale that accounts for ecosystem services since the ecological links and dynamics that human activities affect or rely on are usually contained within the catchment boundaries. As a result, they can be integrated into a river basin plan where trade-offs can be analyzed by upstream and downstream stakeholders, and decisions made on the basis of holistic understanding. Large basins such as the Gandaki contain many nested scales including sites, small catchments, and sub-basins such as the Seti and Marsyangdi. In 2015 the Ministry of Forests and Soil Conservation (MoFSC) recognized the Gandaki basin as a conservation landscape with the goal of managing it through an integrated, river basin planning approach which is built on the foundation of climate-smart conservation and sustainable development practices to promote persistence of biodiversity, and sustainable management of natural resources for continued provision of ecosystem goods and services that support equitable and inclusive socio-economic prosperity (MoFSC 2015).

Natural systems are also coming under increasing stress from climate change, and it is important to understand their vulnerabilities and integrate resilience building and adaptation measures for species and ecosystems into planning processes, to maintain ecosystem services for as long as possible, as well as for biodiversity conservation. Reducing non-climate stresses such as overharvesting of forest resources or overgrazing can play a major role in increasing ecosystem resilience (e.g. Hansen et al. 2003), though other climate change-focused interventions will also be needed. For this, information is required on the specific factors that affect system resilience and overall vulnerability. In the Gandaki river basin the natural systems that were found to be most vulnerable include sub-tropical broadleaf forest and semi-desert coniferous forest; the Seti and Rapti sub-basins; spring sources in the Churia and floodplains; and migratory birds and gharial (a crocodile species). Vulnerable man-made systems were rainfed agriculture (pakho) in the mid-hills; agriculture on leveled, irrigated land (tar) in the mid-hills and Siwaliks; and rural settlements and local roads (Table 1) (WWF Nepal 2016a). Hariyo Ban Program and partners have been able to start implementing several of the recommendations from the assessment (Table 2): for example, through a major focus on the Seti sub-basin; promoting climate-smart agricultural practices; promoting alternative energy and improved cook stoves to reduce pressure of firewood collection; and climate-smart community forest management.

Table 1: Most vulnerable ecological and man-made systems in the Gandaki basin

Focus Area	Most Vulnerable Systems and Species	Region
Forests	Subtropical Broadleaf	Siwalik/Churia Range
	Semi-desert Coniferous	Trans-Himalayan Region
Freshwater	Spring Sources	Siwalik/Churia Range
	Floodplains	Basin-wide
Species	Migratory Birds	Basin-wide
	Gharial	Siwalik/Churia Range
Agriculture	Pakho	Mid-hills
	Irrigated Tar	Mid-hills/Siwalik
Rivers	Seti	Sub-basin-wide
	Rapti	Sub-basin-wide
Infrastructure	Rural Settlements	Basin-wide
	Local Roads	Basin-wide

(WWF Nepal 2016a)

Table 2: Proposed Adaptation Interventions

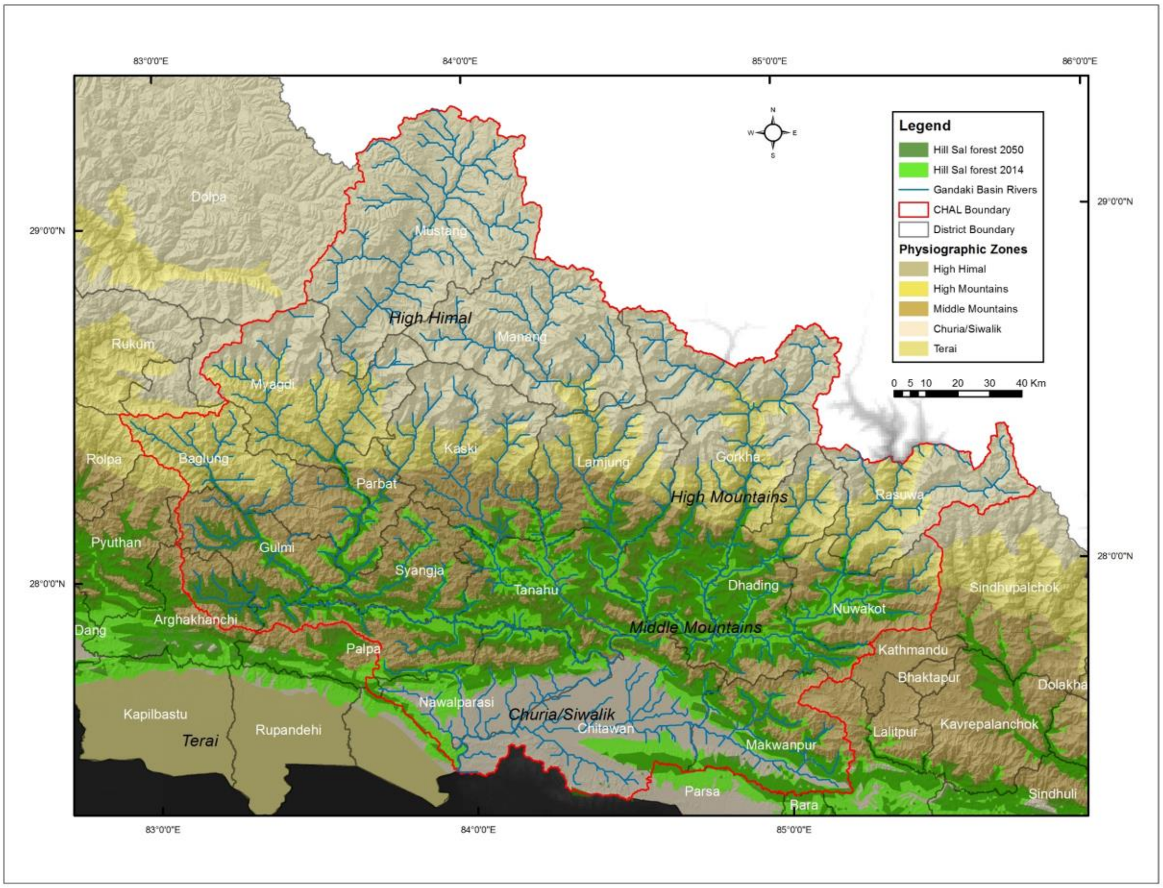
Focus Area	Proposed Interventions
Forests	Promote alternative energy sources and improved cook stove programs to reduce fuel wood demand and deforestation/degradation
	Promote "climate-smart" community based forest management, focusing on fire prevention and control, and afforestation in denuded areas
Freshwater	Enhance monitoring for freshwater systems, focusing on glacial extent and snow line, and snow-water equivalent in higher altitudes; and water quality in lower lying areas of the Mid-hills and Siwaliks
Sub-catchments	Install early warning systems in floodplain communities that regularly experience flooding, alongside climate change sensitization and disaster preparedness programs
Species	Identify and conserve important winter/nesting areas for altitudinal migrant birds, based on projected habitat changes according to climate scenarios
	Work with upstream watershed communities to reduce fertilizer and pesticide use and develop soil management practices to reduce runoff and siltation.
Agriculture	Increase funding for agriculture extension services, including for climate-smart farming techniques and overall climate change awareness
	Improved access to seasonal climate information for farmers, including suggested planting dates and weather forecasts
Infrastructure	Mandate climate vulnerability assessments for all proposed large infrastructure developments, including national roads and hydropower dams
	Eliminate unplanned road construction through incentives for "green roads" construction alternatives that have proper drainage and gradation.

(WWF Nepal 2016a)

Maintaining connectivity and enabling species shifts: River basins span altitudinal gradients; the Gandaki basin is an extreme example with an altitudinal range from a few hundred meters to over 8000 m, with eight major vegetation zones from lowland Sal forest to subalpine scrub (Thapa et al. 2016). As temperatures rise, many species will respond by shifting their range distributions, usually upwards. This was modelled for selected tree species, to help develop guidance on species for tree planting in light of climate change (WWF Nepal 2016c). For example, Figure 1 shows projected distribution of sal (*Shorea robusta*) in 2050 using the IPCC A2A greenhouse-gas emissions scenario (the highest IPCC GHG emission scenario; note the caution about using modelling results below). Under this projection, sal is likely to disappear from many low-lying areas in the Terai that are not refugia, and to shift further north along the river valleys to the north of the Churia range and up the surrounding slopes. Given the east-west running ridges in much of the basin, many of the tall south-facing slopes are likely to become pose barriers for northward movement as they become hotter and drier with climate change; hence the river valleys that cut through them are likely to be very important for facilitating climate-induced range shifts of many plant and animal species. They are already used by birds and fish during traditional seasonal migrations.

Figure 2: Projected distribution of sal (*Shorea robusta*) in 2050 using the IPCC A2A greenhouse-gas emissions scenario.

(Caution: the A2A is the highest IPCC GHG emission scenario. Different results would be obtained using other scenarios. To accommodate uncertainties of climate projections, this model and analytical process should be considered and evaluated against other knowledge.)



(WWF Nepal 2016c)

Well planned and managed river basins can provide large blocks and corridors of intact habitat for freshwater and terrestrial species to shift along, and promote adaptation of systems and species. While it is too early to know how successful uphill movements of whole systems or vegetation types will be given the complex ecological inter-dependencies, maintaining and enhancing corridors between them improves the chances for successful adaptation. Special management for areas that are natural climate refugia can help conserve species that may disappear from surrounding areas (local-level refugia are likely to include north-facing slopes and steep river valleys which are cooler and more humid than surrounding areas). The Gandaki basin-scale vulnerability assessment used connectivity as one of its criteria for testing resilience of natural systems (WWF Nepal 2016a); the Hariyo Ban Program is working to restore terrestrial connectivity in priority areas such as the Seti sub-basin in places where it has been interrupted, and to identify potential climate refugia for special management. Unfortunately, existing and planned hydropower development on all the main rivers of the basin (WWF Nepal 2014) is becoming a major impediment for freshwater connectivity and adaptation, a phenomenon that is increasingly common in the Himalaya. Long-term monitoring plots are being established to monitor the impacts of climate change on both terrestrial and freshwater biodiversity and the local communities who depend on these natural systems, along the altitudinal range of the Gandaki basin.

Enabling holistic, climate-smart planning for economic development: In Nepal's river basins, climate change impacts will be manifested in a matrix of different land uses, including new development. Infrastructure development is essential for the country's development, and includes hydropower projects, transmission lines, large-scale irrigation, local and national roads, and expanding settlements and industry. However, many (though not all) infrastructure developments have weak environmental impact assessment and mitigation measures (WWF Nepal 2014). Many roads and dams in particular are having or are likely to have major adverse environmental and social impacts; and high demand for building materials, including for post 2015-earthquake reconstruction, is increasing destructive mining of sand, gravel and stone in many rivers and fragile forest areas. Large-scale development and reconstruction projects also attract labor, resulting in out-migration from farms, which may in turn lead to increased erosion of fallow abandoned lands (for example if terraces erode). Some of these are reverting to forest, but many are being overtaken by invasive species.

These environmental costs of development are likely to be exacerbated by climate change. For example, heavier rainfall is likely to intensify erosion and landslides from poorly designed and constructed roads; thus, road design should take climate change into account, with ability to cope with heavier storms and rising temperatures (WWF Nepal 2014). Hydropower plants, particularly run-of-the-river types, are highly dependent on predictable runoff patterns. But changing precipitation patterns make for unreliable flows, especially during the dry season, and also increase the risk of flooding (e.g. from glacier lake outburst floods, landslides blocking rivers, and intense localized rainfall), which could jeopardize the viability of these power plants. Increased sediment loads due to more intense rainfall—which are already high in the Gandaki basin from natural erosion, deforestation and poorly constructed roads and other infrastructure—will accelerate mechanical damage to machinery, including turbines. The combination of multiple hydropower developments on the same river, along with climate change effects, could have a major impact on the success of hydropower generation.

Results of an environmental flows analysis[6] being undertaken in the Kali Gandaki stem of the Gandaki from Mustang to Chitwan will soon be available, which will improve understanding of

[6] An environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated. Environmental flows provide critical contributions

flow requirements for targets such as traditional agriculture, domestic water supplies, water-based tourism, connectivity for aquatic organisms and fisheries, wetlands in Chitwan, and religious and cultural practices along the river. It will enable scenario planning for different climate change and development scenarios to project impacts on ecosystems and the critical services they provide for people in the basin; and provide a tool to develop solutions through improved siting, design and operation of hydropower, taking into account the combined effect of hydropower projects, including storage dams. A large-scale integrated river basin management approach is essential to increase the resilience of these projects, and to provide optimal outcomes for both people and ecosystems.

Need for a multi-sectoral, multi-scale, participatory approach

As people and species strive to adapt to climate change, there will be increasing tension between sectors, upstream and downstream human communities, and even countries over shared resources and ecosystem processes. Using river basins as a planning unit provides a holistic approach that can integrate adaptation planning across sectors around shared water and land resources: agriculture, forestry, fisheries, water, energy, transport, settlement, conservation, and health. A multi-disciplinary approach that facilitates horizontal coordination across sectors will be essential to tackle the challenges ahead, building resilience and facilitating adaptation to hazards that include less predictable precipitation, and increased risk of landslides, floods, drought, and uncontrolled forest fire. Horizontal coordination and collaboration at local levels among neighboring community groups is critical to enable them to manage shared resources such as forests and water more effectively and tackle common hazards. It is especially important to identify and take into account the needs of the most vulnerable people, who are often women, the poor and marginalized groups. In the Gandaki basin the Hariyo Ban Program is working to empower and educate these stakeholders about their rights and about climate change, so that they can take part in vulnerability assessments and community-level adaptation planning, ensuring their needs are adequately covered.

Climate adaptation cannot take place in a vacuum; it needs to be mainstreamed with official planning processes at different levels. Nepal being a highly disaster prone country, disaster risk reduction planning is already occurring in many districts but in a parallel process to climate adaptation planning, through the preparation of local disaster risk management plans. Since there is a large overlap between disaster risk reduction and climate adaptation, Hariyo Ban has been working with the National Network of Community Disaster Management Committee and its chapters to pilot the integration of climate adaptation and disaster risk reduction planning (CARE 2016 a). It has also collaborated with village development committees (the lowest level of government) to mainstream adaptation and DRR into local government planning, in order to institutionalize DRR and adaptation, bringing local stakeholders' inputs as well as ecosystem aspects, and leverage funds for implementation (CARE 2016 b).

Vertical integration is also essential, with two-way communication and collaboration among local, district or sub-basin, river basin, national and transboundary levels. In planning processes it is

to river health, economic development and poverty alleviation. They ensure the continued availability of the many benefits that healthy river and groundwater systems bring to society (Dyson et al. 2008).

important to ensure that the traditional water needs of downstream communities and ecosystems are met even as far as possible, in light of future climate change scenarios as well as large-scale infrastructure development. As the new federal structure is introduced in Nepal, following the promulgation of the Constitution in 2015, planning processes need to be adapted for the new levels of government and jurisdictional boundaries, and capacity needs to be built among new office-bearers for this. Provincial boundaries dissect the basin; it is important to promote collaboration among the provinces that will share the Gandaki basin (upstream/downstream, and left/right banks). There are good opportunities for benefit sharing arrangements among the three new tiers of government, for example from hydropower, and payments for ecosystem services mechanisms.

Importance of sound policy, planning, governance and institutions

To facilitate integration, climate adaptation should be mainstreamed into integrated river basin plans, rather than treated as a separate activity. Plans should incorporate scenario planning given future uncertainties, with built-in flexibility. Trade-off decisions are inevitable, for which multi-disciplinary economic, social and environmental analyses, and participatory and equitable decision-making will be needed. Successful river basin management requires an effective and impartial coordinating institution with the authority and mandate to act, and is accountable to all stakeholder groups (Cook et al. 2011). It also must be able to coordinate across political boundaries when catchment boundaries transcend political boundaries. Coordinating institutions will need to be much more flexible in the future to allocate water and natural resources in the face of increasing climate variability, uncertainty and extreme events, and be willing to test innovative approaches, learn and adapt. Finally, policies should be harmonized to avoid existing contradictions and overlaps which could constrict the coordinating body’s ability to act and adapt.

Conclusion and way forward

As climate change advances, it is critical to proactively plan and prepare for change in an innovative, integrated and flexible way to maintain ecosystem services, resolve competing needs, ensure the rights of vulnerable groups, and avoid maladaptation. River basins provide a sensible natural geography-bounded unit to assess and analyze the ecological dynamics, and to bring stakeholders together at multiple scales to manage shared resources more effectively, ultimately increasing the resilience of people, infrastructure and ecosystems. The Gandaki basin offers an ideal opportunity to demonstrate these principles, but will require strong leadership, political commitment and technical inputs to make it happen.

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