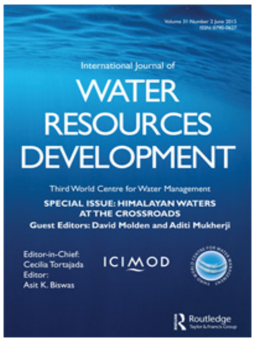

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Governance and management of local water storage in the Hindu Kush Himalayas

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The people of the Hindu Kush Himalayan region face severe seasonal water shortages due to the high variability in rainfall, and the problem is likely to be exacerbated under climate change. Small-scale local water storage options offer a means of collecting monsoon precipitation to provide for agricultural and household needs over the entire year, and they help build community resilience. Proper watershed management, with due consideration of upstream–downstream linkages, and appropriate institutional arrangements are vital for this adaptation measure to work. Active participation of local users in decisions related to water allocation and community services is essential. Planned interventions should preserve the institutional arrangements of reciprocity and cooperation among community members.

Keywords: Hindu Kush Himalayas; water storage; adaptation; local governance; user participation

Introduction

The Hindu Kush Himalayan region (HKH) is the source of 10 major rivers. With its vast reserves of water in the form of snow and ice, it is seen as the water tower of Asia. Nevertheless, communities in this region and downstream face seasonal water scarcity on a regular basis as a result of the high intra-annual rainfall variability, with too much water in the wet season, leading to floods and other natural disasters, and too little in the dry season, resulting in drought and crop failure. Climate change is expected to exacerbate the problem, with increases predicted in both precipitation variability and extreme events (Immerzeel, 2011; Immerzeel, Beek, & Bierkens, 2010). The critical issue is how to store some of the massive quantities of rain falling during the four-month monsoon period so that it can be used over the entire year.

There are three main approaches to adaptation to water scarcity and building resilience to low water availability: (a) developing water storage facilities, both natural and artificial, surface and groundwater, and blue and green; (b) adopting techniques that help increase agricultural water productivity through water-saving practices; and (c) changing the structure of economic activities, say from farming highly water-intensive crops to farming crops that need less water (Asian Development Bank, 2013). While all three approaches are important in the HKH, enhancing water storage is particularly relevant, as intra-annual precipitation is very uneven. Annual precipitation would be sufficient to meet requirements in most places, but it falls within a short period of time and is lost as runoff. Storage can help ensure that a part of the monsoon precipitation remains available

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during the long dry season. A number of studies have suggested that water storage may also become a key strategy for climate change adaptation (ICIMOD, 2009; McCartney & Smakhtin, 2010).

Most commonly, the concept of water storage is associated with hydropower and dams, especially large reservoirs (DFID, 2009). These can have both advantages and disadvantages, and debate on the upstream and downstream impacts of water storage projects involving large reservoirs is extensive (Biswas, 2004; Duflo & Pande, 2007; Tortajada, Altinbilek, & Biswas, 2012; World Commission on Dams, 2000). There is another approach to water storage, however, which focuses on small-scale and very-small-scale local storage systems. Individuals and communities can establish locally appropriate systems for storing water at times of low requirement and high availability for use at times of high requirement and low availability. Such systems directly benefit those who establish them, and both the systems and the associated institutional arrangements can help build community resilience. When applied over a very wide area, they can also contribute to increasing water availability at a national scale. However, they are often overlooked in government strategies, and may even be discouraged by rules and regulations designed to meet the needs of more centralized approaches. This article looks at local systems of water storage from the perspective of local water governance and institutional barriers based on a literature review. Different systems are discussed using a group of published case studies from various ecological regions and a framework based on the pioneering contributions of Ostrom (1990, 2010). The key role of local community and government institutions is emphasized.

Water storage in the Hindu Kush Himalayas

The need for water storage

In much of the HKH region, around 80% or more of the annual precipitation falls during the four-to-five months of the pre-monsoon and the monsoon season, which is followed by a long dry season (Molden, Vaidya, Shrestha, Rasul, & Shrestha, 2014, Fig. 2, p. 63). As a result, six of the eight countries in the region have a monthly rainfall variability of about 100%, as measured by the coefficient of variation (Mitchell, Hulme, & New, 2002). However, the inter-annual rainfall variability is less extreme and, except in Afghanistan, China, and Pakistan, the mean annual precipitation is higher than the global average on land (Table 1). This suggests that there are good prospects for considering local water storage as a means of building resilience to seasonal water scarcity.

Such a strategy could be vital for ensuring livelihoods because the hill agriculture in the region is largely rainfed – more than 50% of the cultivated area is rainfed in all countries except Bangladesh and Pakistan (Table 1) – and thus subject to the extreme changes in precipitation. Traditionally the focus of investment in rainfed agriculture has been on soil and water conservation. Since the key challenge is to reduce water-related risk due to the high seasonal rainfall variability, rather than coping with an absolute lack of water, water infrastructure investments are also required to help add new freshwater to the system by capturing rainfall that falls within and outside the farmland. This indicates the need to consider possibilities for developing seasonal water storage capacity for agricultural and domestic uses.

Approaches to water storage

Water can be stored in many different ways; thus there are many options for increasing storage capacity (Figure 1). The different forms of water storage have been discussed in

Table 1. Agricultural value and water withdrawals by agriculture in the Hindu Kush Himalayan countries.

Country	Value added in agriculture, as a percentage of GDP in 2011	Cultivated area in 2009 ('000 ha)	Proportion of cultivated area equipped for irrigation (%)	Annual agricultural water withdrawal (billion m^3)	Precipitation rate[a] (mm/y)
Afghanistan	31	7910	42 (2002)	20 (1998)	300
Bangladesh	18	8549	60 (2008)	31 (2008)	2700
Bhutan	18	100	28 (2007)	0.3 (2008)	1700
China	10	124,320	48 (2006)	358 (2005)	600
India	17	169,623	39 (2008)	688 (2010)	1100
Myanmar	38	12,135	20 (2004)	30 (2000)	2100
Nepal	37	2,520	47 (2002)	10 (2005)	1300
Pakistan	22	21,280	94 (2008)	172 (2008)	300

Source: FAO AQUASTAT (www.fao.org/nr/water/aquastat/countries_regions.stm); UN-ESCAP (2013); World Water Assessment Programme (2006).
[a] Average precipitation (1961–1990 from IPCC) (World Water Assessment Programme, 2006).

detail in earlier publications (ICIMOD, 2009; McCartney & Smakhtin, 2010). The focus in this article is on local storage systems that help communities meet their needs for water for agriculture and daily use. These include augmenting natural systems of water storage such as glacial melt and snow melt, mountain springs, soil moisture and high-altitude wetlands through initiatives such as wetlands conservation and watershed management in the hills and mountains, groundwater aquifer recharge through infiltration ponds and others in the foothills, and even creation of small artificial glaciers (Andermann et al., 2012; Sudhalkar, 2010; Trishal & Kumar, 2008). They also include construction of artificial systems such as small ponds and tanks for rainwater harvesting, which can be built on

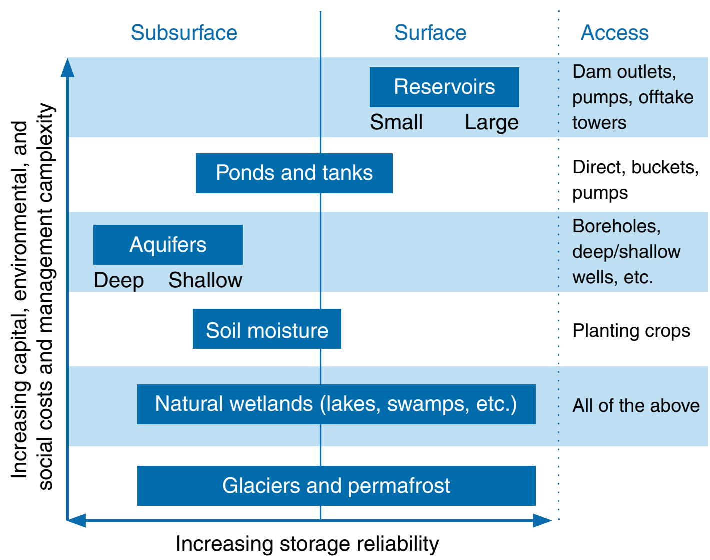

Figure 1. Water storage options.
Source: Adapted from McCartney and Smakhtin (2010).

farms, and small reservoirs that can be constructed on mountain streams and along natural drainage channels in the hills (Cai, Cui, Dai, & Luo, 2012; Malik, Giordano, & Sharma, 2014). Depending upon the geophysical characteristics of a specific location, a combination of natural and artificial systems could be selected to meet the water needs of a community.

Local water storage as a means of building resilience to seasonal water scarcity

Local water storage can contribute to community resilience to seasonal water scarcity in a variety of ways. First, it provides communities with a measure of control over water availability, and enables farmers to grow crops reliably even when precipitation is scarce. When used together with measures to increase ‘crop per drop’, it can contribute substantially to ensuring food security regardless of changes in patterns of precipitation. It will also support adaptation to climate change, which is projected to result in changes in precipitation patterns rather than changes in annual amount of precipitation.

Second, developing local water storage capacity encourages the development of an appropriate system for watershed management. Such a system will have multiple benefits such as ensuring ecosystem services from the watershed and building mechanisms to support upstream–downstream linkages, which enable the community to respond better to water scarcity as well as to other changes.

Third, the institutional arrangements required to implement local water storage schemes also contribute directly to building community resilience. It has long been felt in policy circles that there is a need for institutional innovation to reduce the cost of collective action for developing and operating water infrastructure (Hayami & Ruttan, 1985). A recent special report concluded that a sustainable equilibrium between water supply and demand in agriculture, the largest user of water, is most likely to exist under the democratic self-governance and active participation of scientifically well-informed farmers (The Economist, 2010). This is especially true for local water planning and management for storage capacity development. Appropriate institutional arrangements are necessary for local water storage schemes to encourage local user participation in decision making and establish a system of reciprocity among the community members, thus empowering the community and enabling the development of robust local institutions that provide a foundation to address other challenges.

Biophysical and institutional challenges to local water storage

Although there is clearly both a need and a potential for increasing local water storage capacity to meet community needs, there are a number of challenges. They can be broadly divided into the biophysical and the institutional. On the biophysical side, there are knowledge gaps concerning scientific information about groundwater aquifer systems, wetlands, watershed management, and the response of glacier systems to climate change; on the institutional side, the barriers have to do with crafting institutional arrangements for water governance and management. Some of the knowledge gaps and needs for building institutional capacity for water storage options are summarized in Table 2.

Traditional institutional arrangements for local storage in the Hindu Kush Himalayas

A number of institutional arrangements have been developed over the years by the communities of the Himalayan region in their attempt to develop and maintain local water storage systems and distribute the water benefits within the community. There are few

Table 2. Knowledge gaps and institutional requirements.

Strategic elements and options for water storage	Knowledge gaps	Institutional capacity building needs	
		Community water governance	Rewards and compensation for ecosystem services
Wetland conservation	Need to understand the vulnerability of wetlands	Need mechanism for communities depending on wetlands to participate in wetland conservation	Need mechanism for downstream users to reward upstream communities for wetland conservation and management
Water harvesting and watershed management, including soil moisture maintenance	Need to study traditional institutions of water storage management	Need mechanism for active community participation in watershed management	Need mechanism for downstream users to reward upstream communities for good watershed management
Groundwater aquifer recharge	Need to gather information about groundwater aquifer systems	Need community-level mechanism for aquifers to be developed based on the principles of shared construction and maintenance costs	
Reservoirs for water storage	Need to explore the potential of using natural lakes for storage; need to examine the potential for harnessing and storing of glacial and snow meltwater at high altitudes	Need mechanism for making local community contributions for construction and maintenance of reservoirs and for allocating water to local farms and families	Need mechanism for sharing costs and benefits of storage reservoir projects between upstream and downstream communities
Glacier meltwater harvesting	Need to understand the response of glacier systems to climate change	Need to develop and institutionalize glacier mass balance monitoring schemes	

Adapted from Schild and Vaidya (2009).

reports specifically on such systems in different ecological zones and socio-economic situations, but there is one very useful study by Agarwal and Narain (1997) that addresses these issues. The authors documented traditional institutional arrangements for water harvesting in various ecological regions of India. Five of the case studies in their publication are described in the following as examples of different types of institutional arrangements. The success and failure of these systems are analyzed in the subsequent discussion in terms of the framework of best practices or 'design principles' for successful governance of common-pool resources suggested by Ostrom (2010). The framework is based on an extensive meta-analysis of case studies on common-pool resource institutions that had endured for a long time. The basic methodology used by Ostrom to validate the best practices relies on game-theoretical experiments in university laboratories and field experiments which suggest that the three critical elements in achieving a cooperative outcome in collective action problems are an identifiable and stable group of participants; a mechanism for face-to-face communication among the members of the group; and a mechanism for monitoring and sanctioning free riders. Ostrom summarized the eight best practices as follows.

- 1a. User boundaries: Clear and locally understood boundaries between legitimate users and non-users are present.
- 1b. Resource boundaries: Clear boundaries that separate a specific common-pool resource from a larger socio-ecological system are present.
- 2a. Congruence with local conditions: Appropriation and provision rules are congruent with local social and environmental conditions.
- 2b. Appropriation and provision: Appropriation rules are congruent with provision rules; the distribution of costs is proportional to the distribution of benefits.
- 3. Collective-choice arrangements: Most individuals affected by a resource regime are authorized to participate in making and modifying its rules.
- 4a. Monitoring users: Individuals who are accountable to or are the users monitor the appropriation and provision level of the users.
- 4b. Monitoring the resource: Individuals who are accountable to or are the users monitor the condition of the resource.
- 5. Graduated sanctions: Sanctions for rule violations start very low but become stronger if a user repeatedly violates a rule.
- 6. Conflict-resolution mechanisms: Rapid, low-cost, local arenas exist for resolving conflict among users or with officials.
- 7. Minimal recognition of rights: The rights of local users to make their own rules are recognized by the government.
- 8. Nested enterprises: When a common-pool resource is closely connected to a larger socio-ecological system, governance activities are organized in multiple nested layers.

Case 1: Glacier meltwater harvesting in the trans-Himalayan region

Harvesting water from glaciers is a common tradition in certain regions of the HKH. In the Spiti Valley of Himachal Pradesh in India, *kul* (diversion channels) are used to tap distant glaciers for water and supply it to a village. The *kul* can be as long as 10 km and are lined with stones to prevent seepage. They deliver water to a circular underground tank constructed in the village; the flow from the tank is regulated. Water is collected from the *kul* through the night and released into exit channels during the day. The community is responsible for keeping the head of the *kul* at the glacier clean and for repairing and maintaining the system: contributions in labour and in kind are made on a voluntary basis by each household, although more recently shortage of labour is hampering the tradition.

According to local tradition, water use rights belong to those families who were the original settlers of the village, and thus the user and resource boundaries of the system are clearly defined. But even among the original settlers the allocation of water shares may be unequal because the shares are renewed and adjusted every season based on demand and other users. The rights of the original settlers are protected because the shares cannot be "lent, sold, or disposed of in perpetuity". However, recent government intervention in water management has had a counterproductive effect. The government rules stipulate that water be distributed equally; but this has had a negative impact on the traditional system, under which water was distributed according to availability and farmers' needs. There has also been a breakdown in the traditional system of provision of community labour, in part because the farmers feel that the government can afford to hire paid labour.

Case 2: Tapping mountain water in the western Himalayan region

Mountain streams are an important source of water in the hill region of Himachal Pradesh. The streams are tapped for irrigation water via a *kuhl* (channel), which typically irrigates an area of about 20 ha (Agarwal & Narain, 1997). The user and resource boundaries are clearly defined, and rights are not limited to a specific group. The village council (*panchayat*) is the ultimate authority on water use rights if and when a conflict arises.

The community has a traditional water tender (*kohli*) responsible for the distribution of water. The *kohli* is a farmer and water user from the community, whose family has been given this hereditary responsibility. The *kohli* has sole responsibility for managing the water allocation and provision of community labour services; he is accountable to the *panchayat* and is paid by the other users with a quantity of grain equal to the weight of the seeds sown. It is the *kohli*'s responsibility to mobilize voluntary labour from the community at the start of each farming season to construct headworks and repair the canal, and for any other necessary tasks. Participation is compulsory for each user, but labour substitutes are permitted. Any dispute between the *kohli* and the users is resolved by the *panchayat*; the council may punish any person found guilty of charges. However, participation in the provision of labour services seems to be declining in recent years. The younger generation often prefer to pay a fine. This has resulted in a gradual move from community labour to contractual labour contributions to keep the system operational; in extreme cases the community systems have been handed over to the government authorities.

Case 3: Stream sharing in the western Himalayan region

In some cases mountain streams are tapped by two different communities lying upstream and downstream, with special institutional arrangements developed to operate the system. Two communities in the Almora District of Uttarakhand provide an example. The upstream Ladyura village assembly (*gram sabha*) is comprised of three villages with an area of 40 ha; the downstream Bayala Khalsa village assembly is comprised of three villages with an area of 24 ha. Water use rights for the two communities are assigned by time of day: the upstream community has the right to use water during the day, and the downstream community after sunset (Agarwal & Narain, 1997).

There is no information about the actual distribution of water or the provision of labour services. It is known, however, that the two communities have a long history of dispute over water use. They have a dispute-resolution mechanism, in which the irrigation committee, members of the village assemblies from the two communities, discuss complaints related to compliance with the water-sharing arrangements. The complaints arise partly because the upstream community has fewer hours to tap water during the dry winter season; there does not seem to be any rotational arrangement.

Case 4: Water-harvesting reservoir in a natural drainage channel in the western Himalayan region

Traditionally, the use of ponds for domestic use was quite common in Jammu villages in northwest India. Local community institutions were responsible for mobilizing voluntary labour from the community for annual desilting and pollution control, but these institutions have now become dysfunctional. The local government institutions (*panchayats*) have not been able to revive the tradition of voluntary labour contributions, and most of the ponds are in a state of "utter neglect and disuse".

The institutional arrangements for managing water harvesting for storage reservoirs are traditionally less developed in the region than those for managing simple ponds. This is probably because storage reservoirs require construction and technical and financial support from the government, which was not available pre-independence. However, small reservoirs can be built at a low cost in a short period, and their proximity to the point of use makes them easily manageable by a local community. A small experimental reservoir initiated by the state forest department at Jagti Village, 16 km from Jammu, provides an example of a successful recent arrangement. The small reservoir in Jagti was built in 1988 at a cost of INR 208,000 by erecting a concrete dam 5.49 m high and 23.79 m long across the Bilani *nullah* (natural drainage channel), which has a 4 km^2 catchment. The reservoir filled in a day because of the heavy runoff and remains full even during the dry season. The Kandi region has many deep, narrow valleys, where more such reservoirs could be built (Agarwal & Narain, 1997).

Case 5: Water harvesting and watershed management in the northeastern hill region

In contrast to northwest India, village ponds are quite common and well maintained in India's north-eastern hill region. For example, there are around 150 small ponds, measuring around 14.5 × 8 × 2.5 m, spread all over the Kikruma Village area, and new ones are being constructed. These ponds form part of a holistic approach to watershed management under which (1) a catchment area is kept under natural vegetation upstream of the pond to serve as a water source during the monsoon; (2) below the catchment area, ponds with earthen embankments are dug to harvest water for irrigation and livestock; (3) a cattle yard is placed below the ponds, fenced with ordinary branches or bamboo, and the cattle are washed with runoff water; and (4) terraced paddy fields are located below the cattle yard, and the runoff water enters the paddy fields rich in manure (Agarwal & Narain, 1997).

The community contributes labour services every year for the maintenance of the channels for these ponds, usually before the onset of the monsoon. The last person tapping the channel, who is locally referred to as the *neipu* (lord), is responsible for mobilizing labour to clean the channel. Water rights are clearly specified with a right of prior appropriation; as with mountain streams, once a person has tapped water at one point, the next person will only be allowed to tap water two furlongs (about 400 m) or more above the first point. If the source of water is a mountain spring, all terraces at the same level and below have the right to share the water equally, whenever the terrace is developed.

Discussion

Physical and institutional challenges

Biophysical barriers

To fully harness the potential of water storage in the HKH, the knowledge gaps on wetlands, water harvesting, aquifers, glacier systems and others will need to be addressed. Scientific information is needed to supplement the local knowledge available in communities, especially as historical experience is no longer sufficient to address the changed situation under climate change and the need for adaptation. The local offices of government agencies and non-governmental organizations need to provide scientific information and technical support to communities making decisions concerning water use. Andhra Pradesh's Farmer Managed Groundwater Systems project is a good example of training a community to use scientific information to conserve and manage groundwater in the most appropriate way (Asian Development Bank, 2013). The project has established 63 hydrological unit networks that cover 555 community-based groundwater management committees. Farmers are trained at water schools run by the hydrological unit networks, where they learn to measure and record rainfall, the water table, and their withdrawals. They also learn to calculate how much water can be made available if the water table is not to fall. They use scientific information to draw up a water budget as a group, make agreements about which crops will be grown by each family, and display the information publicly. In the three years after the project went into operation, 42% of the hydrological units were able to consistently reduce the lean-season draft, 51% were able to reduce the draft intermittently, and only 7% had experienced an increase in draft.

Institutional barriers and Ostrom's design principles

The institutional arrangements needed to support development and exploitation of local storage were analyzed by looking at the five case studies using the framework of best practices for successful governance of common-pool resources suggested by Ostrom (see above). In this framework, collective action and monitoring in common-pool resources are solved in a reinforcing manner when the users of the resource design their own rules (for example, the rules that define who has rights to withdraw water), have clearly defined user and resource boundaries, effectively assign cost in proportion to benefits, have rules enforced by local users or those who are accountable to them, and use graduated sanctions that depend on the seriousness and context of an offence. The operation of these five best practices is bolstered by three other design principles. The first points to the importance of access to rapid, low-cost, local arenas to resolve conflict among users or between users and officials; the second states that when the local users have basic recognition of the right to organize by a national or local government, they are able to enhance their capability to develop ever-more efficient regimes over time; and the third states that when common-pool resources are somewhat larger, successful systems tend to be characterized by the presence of governance activities organized in multiple layers of nested enterprises (Ostrom, 2000, pp. 151–152).

The extent to which the governance system in each of the case studies met the principles of Ostrom's 'best practices' is summarized in Table 3. The analysis was drawn from the detailed presentation in Agarwal and Narain (1997) of the case studies outlined above. The governance systems in all the case studies met the design principles concerning user and resource boundaries, congruence with local conditions, collective-choice arrangements, and monitoring users and resource. This has helped them succeed, although the distribution of costs is not always proportional to the benefits. Recent interventions by the government, however, have had a negative effect in some cases because they have interfered with the traditional arrangements under which users make their own rules. In one case, despite some effort, the local government has not been able to revive the traditional arrangements for resource provision. In others, however, local government institutions have helped to resolve disputes regarding water use rights, for example in the case of the *kuhl* in Himachal (Case 2) and stream sharing in Uttarakhand (Case 3). Furthermore, local offices of government development agencies can play a crucial role in mobilizing financial, technical and human resources, as in the case of small-reservoir

Table 3. Ostrom's design principles (best practices) for common-pool resource institutions and the Hindu Kush Himalayan cases.

Design Principle	Case 1	Case 2	Case 3	Case 4	Case 5
1a. User boundaries	√	√	√	√	√
1b. Resource boundaries	√	√	√	√	√
2a. Congruence with local conditions	√	√	√	√	√
2b. Appropriation and provision	?	√	?	?	√
3. Collective-choice arrangements	√	√	√	√	√
4a. Monitoring users	√	√	√	√	√
4b. Monitoring the resource	√	√	√	√	√
5. Graduated sanctions	?	?	?	?	?
6. Conflict-resolution mechanisms	?	√	√	?	?
7. Minimal recognition of rights	Recent government interventions	Recent government interventions	?	Local government institutions not able to revive the tradition	√
8. Nested enterprises	n/a	n/a	n/a	n/a	n/a

construction in Jagti Village (Case 4). The governance approaches are discussed in more detail in the following sections.

Local user participation

The case studies documented by Agarwal and Narain (1997) and the literature on the community management of natural resources indicate that active participation of local users is vital to the success of water governance (Lam, 1998; Ostrom, 2010; Pradhan, 1989). In Cases 1, 2 and 3, the local community institutions played a vital role both in the allocation of water and in the provision of community services. There was a high level of user participation in creating the right institutional environment for making and enforcing the rules and providing community services for operation and maintenance.

While community-managed systems are attractive, deliberately planned efforts may have to be made to develop appropriate community organizations. The 900 ha Pithuwa irrigation system in Nepal evolved from an organization on one branch at the tail of the system: "one prominent farmer took the initiative to organize other farmers on Branch 14 into a committee, which formulated rules for water allocation and distribution along Branch 14. Other branches started to follow the example set by the farmers of Branch 14" (Ostrom & Gardner, 1993, pp. 105–106). While such community leadership is always welcome, proactive efforts may have to be made to set up a community organization with the help of 'social mobilizers', as communities in the traditional sense may be rapidly disappearing, as seen in Cases 2 and 4. Such a social mobilization process was successfully used to form community organizations for the UNDP/World Bank Rural Energy Development Programme and the UNDP Rural Urban Partnership Programme in Nepal.

Role of the government

In Cases 1 and 2, government intervention hurt rather than helped the community. The root of the problem lies in the declining level of user participation in water governance and management. In this context, a study in Chitral in Pakistan is interesting as it compares the results in a community-managed irrigation system, a government-managed irrigation system, and an improved modern community-managed irrigation system (Nadeem, Ahmed, & Younis, 2012). The results showed that the most important point was whether local user participation was ensured in making and enforcing rules, not whether the system was managed by the community or the government, as highlighted in Ostrom (2010) (citing Grafton, 2000). The most successful system in terms of local user participation in decision making and equitable distribution of water resources was the improved modern community-managed system.

Government intervention in community-managed systems should not disturb existing reciprocity mechanisms as these are an important element in the success of traditional institutional arrangements. In storage reservoirs for irrigation, there are three types of problem: water allocation to the farmers; maintaining the irrigation system; and asymmetry in bargaining power between head-enders and tail-enders. External resources may be used to provide skilled labour, materials and equipment, but local resources are often preferable for unskilled labour, which should be provided by both head- and tail-enders to help maintain patterns of mutual dependency and reciprocity between farmers and avoid problems of asymmetrical bargaining power and resultant inequality in water availability at the two ends.

The Pithuwa irrigation system, discussed earlier, provides a good example. The Department of Irrigation took the lead in constructing and lining 16 branch canals, but did not build a permanent intake structure. This helped maintain reciprocal cooperation between the head-enders and tail-enders. Rules for the allocation of water were set by the farmers; operation and maintenance of the temporary intake structure required cooperative efforts between the head- and tail-enders, and was also gradually turned over to the farmers (Ostrom & Gardner, 1993).

The 40 ha Yampa Phant farmer-managed irrigation system in Nepal is another good example of maintaining reciprocity (Ostrom & Gardner, 1993). Farmers built a permanent storage structure to retain water from a perennial spring. Here, there was no need for head-enders to depend on tail-enders for labour mobilization during the spring to build or repair headwork, but there was a need for labour to desilt the reservoir each year before the onset of the monsoon, and for the daily upkeep of the 12 outlets during the monsoon season. Both these activities motivated cooperation between head-enders and tail-enders.

Water harvesting and watershed management

Rarely will a large storage facility be feasible, or able to provide services to a large area, in the hills and mountains. There may be lessons to be learned on combining water storage at farm and watershed levels with conservation and management of wetlands and better land use practices, as in Case 5 in which water storage in ponds at various levels of the terraced farms is combined with measures for catchment protection. In a similar way, a hydrological study carried out in an agrarian watershed in Sikkim recommended that dense mixed forest cover should be maintained in the higher-elevation catchment areas to regulate and ensure stream flows downstream (Rai & Sharma, 1998). More recently, application of geohydrological techniques for identifying recharge areas of unconfined aquifers in mountain areas has been suggested to support watershed management in the context of changing precipitation patterns (Tambe et al., 2012). Some watershed development programmes in India have started to focus on water harvesting and improving soil health in rainfed areas, rather than the traditional focus on simple soil and water conservation (Rockstrom et al., 2010). In practice, these programmes were facilitated by the formation of the National Commission on Farmers, which adopted an integrated watershed management approach in 2005. This is a reform of previous practice, in which programmes were implemented by separate ministries (Agriculture, Rural Development, Forestry), making integrated watershed management difficult.

Upstream–downstream linkages

While rainwater harvesting in watersheds may help in increasing water availability for upstream farmers, in some cases it may hurt the downstream farmers; an assessment in a semi-arid watershed in Andhra Pradesh found that water-flows out of a developed area declined significantly, hurting the downstream users (Garg, Karlberg, Barron, Wani, & Rockstrom, 2011). If water storage systems upstream result in reduced water availability to communities downstream, these communities may have to be compensated by the upstream beneficiaries. Similarly, if improved management of watersheds and groundwater recharge upstream increase water availability downstream, communities upstream may have to be compensated or rewarded for their efforts. Institutional arrangements for the management of upstream–downstream linkages in watersheds may be complex, as discussed in Case 3, because the externalities may be unidirectional and there is no form of reciprocal cooperation – the hallmark of head-ender/tail-ender dependency.

Institutional barriers are relatively easy to manage when the externalities are positive, such as combined water storage and watershed management upstream leading to higher groundwater aquifer recharge and more water available downstream. They are relatively difficult to manage when the externalities are negative, such as harvesting water upstream for water storage leading to less water available downstream, which may result in an issue of water use rights (Dombrowsky, 2009). The solution may be easier if a negative situation can be transformed into a positive situation, for example by harvesting water upstream in a reservoir and sharing both the additional regulated water and the cost of reservoir construction with downstream users. Institutional mechanisms for concrete financial transactions between upstream and downstream communities may have to be developed.

Conclusion

Local water storage for building climate resilience continues to be highlighted in the policies of the governments in the Himalayan region. India continues to be strongly committed to watershed development and rainwater harvesting; in its national budget for Fiscal Year 2015, the government announced a new programme, *Neeranchal*, "to give an added impetus to watershed development" (Government of India, 2014). Nepal has also announced plans to prepare a master plan for integrated watershed development in the

Siwalik (Chure) Hills region in its national budget for FY 2015, and has plans to increase drinking water supplies by tapping stream flows, building community ponds in villages, and constructing tanks, and if feasible, reservoirs for harvesting rainwater (Government of Nepal, 2014). These initiatives will help make supplementary funds available and provide technical support where needed. But there are several biophysical and institutional barriers that need to be overcome for the successful execution of such programmes.

First, the fundamental lesson learned from the case studies and other observations is that active participation of local users at all stages is vital to the success of local water governance and management, irrespective of the type of management – community, private, or government. Local users should be at the centre of all activities. The most important point is whether local user participation is ensured in making and enforcing their own rules, in monitoring and taking action against violators, and above all in managing resources, primarily labour.

Second, it is important to ensure that government interventions do not interfere with existing reciprocity mechanisms as these are crucial to the success of traditional institutional arrangements. While making deliberately planned efforts to improve the existing community organizations or to build new ones, it is important to maintain patterns of mutual dependency and reciprocal cooperation between the farmers.

Third, local non-governmental organizations have often played a valuable role in forming and activating community organizations; they can also help ensure that community organizations are representative of the social structure of the community, and empower women and disadvantaged groups in active participation. In many communities, organizations may already exist; in others they may have to be developed with the help of ‘social mobilizers’. There is a need for capacity building of local community institutions for making decisions related to the allocation of water to farmers and households, and the provision of community services from them to the projects at various stages of planning, construction, operations and maintenance.

Fourth, local government institutions, such as village councils and village assemblies, play an important role in dispute resolution, especially in matters related to compliance with water use rights. Although technically water rights belong to the nation (as in Nepal) or the province (as in India), there are many traditional water use rights, and local government may be called upon to arbitrate in water use disputes. Both local government and local offices of government development agencies may have to be involved in channelling funds to a community – or, in some cases, managing the local water storage facility. There is a need for capacity building of local government institutions to facilitate resource mobilization and upstream–downstream benefit sharing and to provide technical support during project execution.

Finally, proper watershed management and consideration of upstream–downstream linkages are vital to successful local water storage initiatives. It is becoming increasingly necessary for water to be managed at a watershed level. Watershed management committees, government agencies, or in some cases non-governmental organizations could play a role in building the capacity of community organizations to use scientific information in their water management decisions. Such information becomes critical when upstream–downstream linkages come into play; communities may often not realize how activities upstream affect water availability downstream, because the effects may have a lag time, sometimes of several years.

In all of these, the private sector may also have a role to play, but that lies outside the scope of the present article. In the future, more cases from the Himalayan region need to be identified and analyzed to draw broad conclusions and identify successful best practices.

Furthermore, it would be useful for future studies to include an assessment of stakeholders' perceptions of water storage practices (both physical and institutional) and of local capacity to implement effective watershed management approaches, to increase understanding of the discrepancy between the potential of local water storage and the actual functioning of local institutions.

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