LIVING WITH CHANGE: adaptation and innovation in Ladakh

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Introduction

General concepts of vulnerability, adaptive capacity and adaptation strategy must be understood in the context of local challenges and opportunities if they are to be useful at the scale of the communities and regions where people live (see Box 1). Although excluded from most national and regional models and studies, Ladakh provides a case study for exploring the ways in which adaptation to environmental change is taking place at community scale, both through the implementation of technologies adapted to suit extreme and changing conditions and through decision making by adaptive and resilient communities. A detailed model of adaptive capacity in Ladakh is beyond the scope of this paper, but the issues highlighted herein may serve as a basis for building such an analysis.

Regional overview

Situated between the Himalayas and the Karakoram, Ladakh is a high-altitude, arid mountain region characterized by climatic and seasonal extremes and challenging terrain. Temperatures in winter drop to -30 degrees centigrade; the summer maximum is around 25 degrees centigrade. Air moisture content is very low. The high-altitude desert supports a unique ecosystem, with 13 animal species indigenous to the region, including the rare Ladakh urial and the endangered snow leopard.

Ladakh is a semi-autonomous region (comprising Leh and Kargil Districts) of approximately 97,000 square kilometres, in the state of Jammu & Kashmir, which is itself semi-autonomous within India (Figure 1). The region is home to about 2.3 million people who trace their ancestry through the Silk Route, and the rich traditions of Ladakh's cultural heritage attract several hundred thousand visitors from around the world every summer. Ladakh society is characterized by seasonal migration, temporary communities and nomadic subsistence farming. In urban and rural communities, families supplement incomes with services to the Indian Army. Due to its geopolitically strategic location and India's unresolved border disputes with China (in Siachen) and Pakistan (in Nubra Valley and along the Line of Control, north of Kargil), Ladakh has hosted a permanent military presence since 1952; today, military personnel stationed in Ladakh are estimated to be almost as numerous as the civilian population.

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Box 1 A note on definitions

Adaptation

Definitions of adaptation, frameworks for assessing vulnerability and adaptive capacity have been variously described and models have been constructed linking vulnerability and resilience (although few examples exist that explore the particular constraints and opportunities among mountain communities). Some authors see adaptation as a deliberate activity: for example, in a review of adaptation in the developing world, Adger *et al.* (2003) see adaptation as planned interventions which facilitate natural, inherent resilience. Mertz *et al*. (2009) see adaptation as making changes in social systems, pointing out that “coping is the short-term response to variability, whereas adaptation is the more fundamental change of the system to allow for a new coping range to be established” (Mertz *et al.*, 2009, p.747). In their study of the application of adaptation in natural systems to human security, Sagarin *et al.* (2010) emphasize the need for decentralization, adaptation and cooperation to achieve security, defining adaptability as “the capacity to change structures, behaviours and interactions in response to selective pressures” in the system environment (Sagarin *et al.*, 2010, p.292). In summary, in search of a definition of adaptation, concepts described in the literature are broadly divided into those that advocate changing the system, and those which are about changing perceptions of the system.

Scale

Discussions of adaptation make the distinction between planned interventions (anticipatory, planned activities) and ongoing, reactive processes which are a feature of social change. Whether planned or reactive, adaptation occurs at a range of scales: in natural systems, among individuals and within and between communities. In many countries, planned adaptation is most evident in the form of national, state-level and regional strategy and policy design; models for describing and assessing vulnerability and resilience are therefore often constructed at national and regional level, for example Brenkert and Malone (2007) assess vulnerability and resilience at state level in India; O’Brien *et al.* (2004) present a method for investigating the vulnerability of India’s agricultural sector to climate change in combination with other global stressors. Approaching adaptation “from the ground, up”, the practitioner community has developed a wealth of tools and practical techniques aimed at enabling community-based adaptation (CBA): a good summary is provided by the IIED (Ashley *et al.*, 2009). Practitioners and policy makers recognize that most adaptive behaviour occurs at the scale of individuals, villages and communities (Jones, 2010), often distant and disconnected from the assessments and models produced in science. In many regions, traversing this divide is a challenge for contemporary adaptation policy. Vogel *et al.* (2007) describe and connect concepts of vulnerability, resilience and adaptation, showing that only an integrated understanding can achieve better translation of science into policy to support adaptation. The challenges arise in connecting local action with national and global decisions (and *vice versa*). If national and state-level policies are to be useful to citizens, translation between scales is necessary and translation must be an ongoing process to capture the dynamic changes within natural and social systems that are at the core of the adaptation process.

Roadside sign, Border Roads Organization, Leh, Ladakh.
Photo: S. Daultrey, December 2010.

Box 2 Flash-floods in Ladakh, August 2010

On 4 and 5 August 2010 over Nimoo-Basgo (west of Leh) and in the early hours of 6 August 2010 over Leh, a highly localized cloudburst set off a flash flood which devastated parts of the city and surrounding villages, inundated the hospital and severed communication lines. Valuable farm lands were buried under mudslides and roads were washed away. For a region which typically receives only 15 millimetres of rainfall in the month of August, this rare and extreme event wrought havoc with an infrastructure which is not designed to withstand such shocks. By 9 August, 172 bodies had been recovered from the mud. Almost 1,000 homes were destroyed or damaged.

A cloudburst is an extreme weather event in which very heavy rainfall occurs over a highly localized area in a very short timespan. Ladakh is not known to be frequently affected by this type of phenomena, although similar localized floods happened in the village of Phyang, west of Leh, in 2003. Cloudbursts in other parts of India happen during monsoon season, over mountain regions in the Himalayas, north-eastern states and the Western Ghats. The cloudburst that devastated Leh was caused by instabilities in the monsoon systems coming from the east and west (which also precipitated the extreme flooding in western China), producing an intense convective cloud cluster which travelled north-west over Ladakh. These clouds produced sudden, intense, highly localized rainfall, setting off flash flooding and landslides.

Geologically, the region around Leh is made up of granite and loose sediments. The mountain slopes around Leh are naturally covered in very loose deposits of rock and silt - the result of millions of years of erosion of the Himalayas. Large fans of this loose sediment can be observed in many locations along the banks of the Indus River. The cloudburst saturated the loose rock and silt, setting off mudslides and sand flows which travelled down the mountain slopes towards the Indus. The destruction at locations throughout Leh district was due to the rapid movement of huge volumes of water charged with mud, boulders, trees, building debris and other objects swept up in the flow. At Choglamsar, south-east of Leh (among the worst affected areas), the debris flow travelled approximately 10 kilometres from the epicenter of the cloudburst spreading up to 2 kilometres. In Leh, the debris flow travelled about 3 kilometres, from an elevation of 3,800 metres to 3,410 metres, mostly confined to stream catchments running through the city. The flow destroyed settlements, the Bus Stand and the BSNL mobile telecommunications hub, and severely damaged the Sonam Norboo Memorial Hospital and the radio station.

Less than one week after the disaster, a task force comprised of representatives of the Hill Council and local engineers began planning and organizing re-housing for displaced and homeless citizens. The immediate challenge was to build homes that would withstand the sub-zero temperatures and provide

Figure 1 Ladakh (comprising Leh and Kargil Districts) is located between the Himalayas and the Karakoram. Some 68 per cent of its total land area lies over 5,000 metres above mean sea level.
Source: Various sources in the public domain.

Water and energy

Ladakh is situated within the upper reaches of the Indus watershed, which in total supports about 120 million people in India (in the states of Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab and Rajasthan) and about 93 million in the Pakistan province of the Punjab (literally, "Land of the Five Rivers") (Figure 2). Careful management of water resources within Ladakh is therefore vitally important, not only for the livelihoods of Ladakhis and the ecosystems of Ladakh, but for the health of the whole river system. The main source of irrigation in Ladakh is surface water, with approximately 10,190 hectares of land around the tributaries to the Indus irrigated by

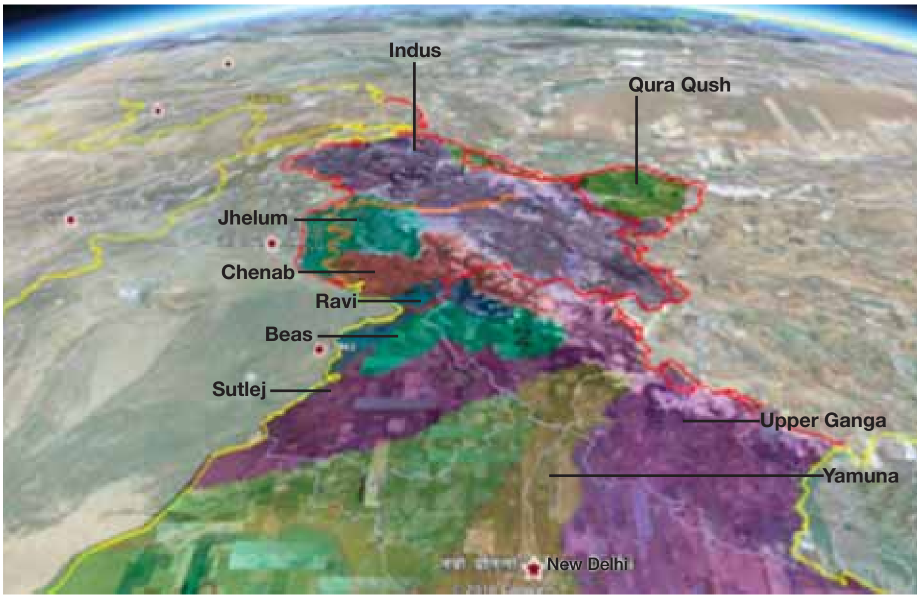

Figure 2 The Indus system in India. Ladakh is situated in one of the most important water towers of the Himalayas. The catchment area of the Indus system within India's national boundaries is about 321,289 km^2 (out of a total 1,165,500 km^2). Average annual runoff in India is about 73 km^3; utilizable surface water about 46 km^3; and estimated replenishable groundwater about 26.5 km^3. The Indus river system contains 29 major dams,10 of which are in India.
Data and composite image based on GoogleEarth; Watershed Atlas of India, Central Ground Water Board, Ministry of Water Resources, Government of India; Transboundary Freshwater Dispute Database.

Figure 3 Artificial glacier at Igoo (altitude 4,206 metres). Diameter approximately 60 metres. Low lateral walls in the naturally formed, snow-fed valley capture snow-melt run-off during the early part of the year. Walls are gradually raised, trapping and freezing the water above. The water is released to the village below in April/May, providing an additional (and guaranteed) source of water for irrigating fields (see inset) before sowing.
Photos: S. Daultrey, April 2009.

a sophisticated and carefully managed system of small, hand-built mud canals, which make effective use of seasonal run-off from melting snow and ice at high altitudes. Irrigation using groundwater is negligible. In some locations (e.g. at Igoo, southeast of Leh, see Figure 3), snow water harvesting using artificial glaciers provides water during the critical first months of the growing season (April to May).

Solar radiation is one of the most abundant natural resources in Ladakh, with annual solar radiation exceeding averages for other areas of India with high insolation (see Table 1) (Purohit and Purohit, 2010). Over the past decade, various government and private schemes have begun to exploit its full potential. For example, a successful solar home lighting scheme introduced in 2000 was the first of its kind in India; solar home lighting is now being extended to include Kargil District. Such off-grid, household-scale technologies are particularly suited to the needs of remote villages comprising small numbers of households.

Another promising natural resource which marks Ladakh out in the Indian subcontinent is its geothermal potential: surveys have identified a geothermal resource at depths suitable for exploration and development (Harinarayana *et al.*, 2006); some estimates suggest potential of as much as 40 megawatts in Puga Valley (southeast Ladakh). This resource could be developed to provide grid-connected power to small

Table 1 Solar radiation estimates for Leh, Ladakh, compared with other cities in India that receive high insolation.
Source: Purohit and Purohit, 2010.

Location	Altitude (m)	Annual solar radiation on horizontal surface (kWh / m² / year)		
		Global	Diffuse	Beam
Jaipur	390	2,087	691	1,396
Ahmedabad	55	2,110	746	1,364
Leh	3,514	2,149	695	1,454

Technology	Number of installations	Installed capacity (MW)
Solar water heating systems	Total 15,000 m^2 collector area (residential, government and commercial use)	n/a
Solar dish cookers	4,500	n/a
Steam cooking systems	15	n/a
Domestic solar greenhouses	2,500	n/a
Commercial solar greenhouses	250	n/a
Solar dryers	500	n/a
Ground source heat pumps (experimental basis)	5	na
SPV power plants, 5 to 100 kWp with battery support (in villages)	40	1.4
SPV power plants, 5 to 10 kWp for institutions (health centres, education institutions, religious institutions)	60	0.5
SPV power plants in defence establishments	5	0.5
Solar PV pumps in co-operative society farms (experimental basis)	5	n/a
Small hydro projects	19	11.2

Table 2 New, renewable energy systems for Ladakh for implementation in 2010-13, supported by a Rs. 500 Crore (approximately US$110 million) funding programme from the Ministry of New and Renewable Energy (MNRE), Government of India. See http://ladakhenergy.org.

settlements and army bases sited on the national highway, using the existing road infrastructure to site an extension to the existing Leh-Srinagar 220 kilovolt line.

The Ladakh Renewable Energy Development Agency (LREDA) is the nodal agency of the Ministry of New and Renewable Energy, Government of India and is currently implementing renewable energy technologies across Ladakh (see Table 2). To date, more than 30 companies from across India (many of which are part of global corporations) have put forward proposals for the execution of solar thermal and solar photovoltaic works (e.g. TATA BP Solar and Reliance). At the time of writing, the four successful solar power companies have been given a target for completion of all works by October 2011. Projects are subsidized in part or whole (from 50 to 100 per cent) by the Government of India, with support-in-kind from the Indian Army in some cases. Other initiatives include the implementation of the solar passive architecture

Strengths	Challenges
Pristine environment	Physical geography, high-altitude desert: altitude ranges from 3,500 m to more than 5,000 m
Excellent solar resource; promising geothermal potential	Large territory: dispersed and small centres of electricity demand
Strong social cohesion at community scale	Regional political conflict driven by interests outside of Ladakh; occupies border region which is politically sensitive

Table 3 Summary of development constraints and opportunities in Ladakh.

Figure 4 Learning by doing: new materials, old technology. Barley, among the most important crops produced in Ladakh, is harvested and milled in August to produce tsampa. Farmland and mills were lost in the floods of August 2010 (Box 2). Sonam Stobgais Tubakpa, village engineer at Igoo, demonstrates his prototype *rantak* (water mill) which will replace the lost mill. In this demonstration, car tyres represent the stone millwheels. Traditional mills use a wooden hop and a wooden mill-wheel immersed in the stream-flow, typically milling 250 kilograms of barley per day. Using new materials to a traditional design, Sonam expects his *rantak* to produce 300 kilograms per day. The new designs will be tested in 2011.
Photo: S. Daultrey, December 2010.

concept in hospitals and medical care facilities, building six 10-kilowatt solar-wind hybrid plants at government schools across the region, and installing micro-hydro devices in villages.

Development in Ladakh

> *Development occurs in the process of learning, not earning, as growth does. Development is not so much a matter of how much one has as it is of how much one can do with whatever one has.* (Ackoff, 2006, p. 6).

Both human and natural systems in Ladakh are in the front line of rapid environmental and socio-economic change (see Box 2). Regional climatic variability, within the broader dynamics of global climate change, is affecting natural and human systems in Ladakh. Practical constraints on development choices include its physical geography, climate and regional and national political conflict. Surface access to the region is constrained by seasonal climatic extremes and high altitude, making the building of new infrastructure to compensate for changes in the natural environment an expensive and challenging proposition (see Table 3). These practical and political issues create a challenging and changing baseline for development and adaptation decisions, whether planned or reactive. However, successful examples are evidenced at all scales.

We define “development” in this paper as the capacity to learn and to exercise freedom of choice in the pursuit of an increased quality of life (see Ackoff, 2006). At the scale of individual communities and as a region, Ladakh exhibits both. For example, following post-flood recovery work in December 2010, local non-governmental organizations (NGOs) initiated a forum to exchange and share learning within and between NGOs operating in the region.

> *By 2025, Ladakh will emerge as [India's] best model of hill area development in a challenging environment, with its sustainability embedded in ecological protection, cultural heritage and human development.* Ladakh 2025 Vision Document, LAHDC.

In 2005 the Ladakh Autonomous Hill Development Council published its 2025 Vision, setting out priorities for meeting the unprecedented challenges that now face the region. Its priorities for water include: the protection of water resources from pollution; arresting the depletion of already limited water resources through conservation, water harvesting and impoundment; improving the distribution of drinking water, especially the design of infrastructure that can withstand extremes of temperature; optimizing utilization and conservation, including restoring traditional systems of water use and sharing; and establishing a master plan for flood protection along the Indus. Strategies for energy are: placing emphasis on renewable sources of energy; promoting energy efficiency; developing the power sector as a commercial industry in its own right; decentralizing power generation, especially in remote regions, with emphasis on involving local communities in the installation, commissioning and maintenance of such systems; and streamlining the region's institutional administration in the energy sector. (LAHDC, 2005).

Discussion

Adaptation is about increasing efficiency, both of the technologies being implemented and the social learning around the use of a technology. Current development initiatives and village-scale projects in Ladakh provide abundant examples of both processes.

Adaptation of technology

Many of the energy systems being implemented by LREDA in 2010-12 require the adaptation of technologies to suit the extremes of environmental conditions in which they will operate. Renewable energy projects in Ladakh range from making incremental changes to existing technology (e.g. modification of traditional water mills for pico-hydro schemes) to the introduction of completely new technologies (e.g. solar-wind hybrid systems). Technology functions most efficiently when it is designed for the environment in which it will operate: the systems being implemented by LREDA are an example of this in practice. The LREDA plan began with a detailed survey, village by village, of development needs (including the present condition of the watershed).

At a highly localized scale, the re-design of water mills in Igoo using new materials to a traditional design (see Figure 4) demonstrates a combination of seizing opportunities given by improved road access (to bring in materials), solving problems at the scale of a small group of households using indigenous knowledge and skills, and learning-by-doing.

Adaptation through policy design and social learning

Policies for Ladakh are generally framed and presented at state and national level, but in practice many decisions happen on the ground. Small issues are often dealt with by the panchayat; big issues are passed on to regional government, but the process often takes too long for people to see results quickly. Therefore at the scale of individual communities, the basis for innovation in Ladakh is often learning-by-doing. The decision process can be summarized as: (1) trust the decision maker that the technology is the right choice for me / my community; (2) implement it; (3) learn how to use it; (4) start modifying it to suit my own needs / the needs of my village. Abundant examples show that advanced education is not a pre-requisite for "doing": in many instances, "doing" is simply about finding people who know how to get things done and getting them in. Education enhances decision making and provides a basic toolkit, but is not the primary foundation for innovation.

Adaptation plans in Ladakh are about striking a balance between preserving the past and innovating for the future. Ladakhi society is composed of small communities. Decisions about new technologies or interventions in the environment, whether planned or reactive (see Box 1), have significant short- and long-term impacts at the local scale and therefore must be sensitive to community needs. The LAHDC 2025 Vision is a successful example of a mid-point between conventional "top-down" decision making by the state government, and community-based decision making. It achieved acceptance because its design, from the outset, was consultative, inclusive and responsive to the issues that are most important to individuals at the scale of their families and communities. The 2025 Vision was adopted in 2005 and forms the basis for current policy making in the areas of energy, water and rural development.

The success of new technologies in Ladakh appears to be influenced by three factors:

- **(i) leadership.** Panchayat leaders are the points of influence and knowledge within the social system at the village scale, directly determining the uptake of new technologies and participation in community-based adaptation;
- **(ii) trust.** Individuals look for ability of an individual to exert influence at community scale, balanced by trust within their community that the person making decisions is doing so in the collective interest;
- **(iii) community size.** Small organizations learn fast. Ladakh is composed of small communities: if someone cannot be trusted, people find out fast. Community-scale knowledge is more about abilities than about the presence of a technology.

Part of the key to success in challenging circumstances is recognizing that difficulties may be transformed into opportunities through the application of innovative design combined with determination to absorb the risks and patience to await the outcomes.

The past is the key to the future

Ladakh has a wealth of opportunities to use indigenous and imported ideas and technology, because it has the human resource (particularly among the younger, university-educated generation), natural capital (some of the best solar resource and geothermal potential in southern Asia), funding (from private investors and national government schemes) and strong social values which remain largely intact despite outside influences. Pressure from national investment schemes combined with growing political influence and the aspirations of a new generation is driving a wave of economic growth and creativity within the region, which has also begun to change the way "outsiders" view this traditionally isolated mountain kingdom.

Ladakh is a civilization of adaptors. Generations of deep links with a trade route that at one time stretched from Istanbul to Beijing has produced a society of nomadic communities. Innovation occurs when there is a flow of knowledge and ideas between different communities. Consequently, "when you are a nomad, you know how to adapt".

Conclusion

Living with change means doing more with less: improving efficiency, both of technologies and in social learning around the use of a technology. Adaptation, whether as a planned intervention or a natural feature of social change, is about changing ways of doing things to increase choices and resilience at the scale of households, communities and regions.

Adaptation occurs at a range of scales: in natural and human systems, individuals and communities. Ladakh offers an ideal environment in which to observe these processes at work: the granularity of understanding about how communities are living with change and what individuals want on the ground is very fine. Adaptation in Ladakh may be defined as: using existing social structures that recognize cultural diversity to achieve cooperation in the pursuit of development objectives; applying creativity and knowledge to use resources judiciously; overcoming short-termism; integration and adaptation of technology to suit the environment, choosing the right technology at the right scale: choosing technologies which match system dynamics (decentralized technologies work well in decentralized communities); harmonizing state-level policies with micro-development plans and the needs of highly dispersed communities; interaction with global knowledge through traditional routes; and utilizing experience and knowledge of a new generation of Ladakhi citizens. A framework for assessing adaptive capacity in Ladakh would include all of these dynamic features of the region, set within the context of India's national adaptation policies.

Using indigenous and imported ideas, Ladakh has a wealth of opportunities to recover from the present challenges imposed by the floods of August 2010 and to plan for a bright future, because it has the necessary human resource, natural capital, funding and strong social values to take advantage of the knowledge fusion which is occurring in modern Ladakh. New, renewable energy systems being implemented in Ladakh are an example of such knowledge fusion and technical innovation in practice. Renewable energy projects in Ladakh are based on a detailed understanding of village needs combined with design modifications to cope with extremes of temperature and other climatic variables, and range from making incremental changes to existing technology (e.g. modification of traditional water mills for pico-hydro schemes) to the introduction of new technologies (e.g. solar-wind hybrid systems). Such innovation occurs because there is a flow of knowledge and ideas within and between different communities. Ladakh is demonstrating that, in living with change, vulnerability can be reinterpreted as opportunity by linking adaptive capacity with innovation.

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