Adapting to climate change in Himalayan cold deserts

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Abstract

Purpose – Climate change affects the natural resource base and poses enormous difficulty for the natural resource-dependent indigenous population of the cold desert region in the high altitude Himalayas. The interplay of climatic and eco-hydrological processes on these fragile ecosystem coupled with increasing anthropogenic pressure, are leading to increasing stress on indigenous agro-pastoral communities and their livelihoods. The purpose of this paper is to summarize the outcomes of a study carried out in the Trans and Western Indian Himalayas to quantify the level of environmental threat and adaptive capacity.

Design/methodology/approach – Field studies were carried out across the cold desert belt in Indian Himalaya. A stratified, nested sampling across four Altitude Bands and three hydrological levels in two bio-geographic regions. A participatory approach blended with scientific field observations and secondary data collection was adopted. Criterion variables were used to identify the "Vulnerability Hotspots" while component indices helped in depiction of key characteristic features of study units.

Findings – Data generated through participatory resource appraisal and scientific field observations were used to determine vulnerable "hotspot's", identifying the driving factors (both anthropogenic and natural processes), and determining focus areas for interventions.

Practical implications – A pilot project on Water Access and Wasteland Development has been initiated in the Western Himalayas that integrates community based natural resource management with infusion of appropriate technology to address water stress and ecosystem vulnerability.

Originality/value – The research results identify target areas and methodologies for intervention, while the pilot initiative strives to ensure that disadvantaged cold desert mountain communities have access to resources and skills for effective management of these resources.

Keywords India, Deserts, Water retention and flow works, Global warming, Natural resources, Landforms

Paper type Technical paper

1. Introduction

1.1 Himalayan cold deserts

The Himalayan range stretches in an arc across northern India and its neighbouring countries between 21°57′ – 37°5′ N latitude and 72°40′ – 97°25′ E longitude, covering an area of more than half a million square kilometres. At the remote, northern end of the trans-Himalayas are located the unique cold deserts – stretching from Kinnaur in the South to Ladakh in the North.

The elevation of inhabited areas in cold deserts ranges from 8,000 to 16,000 ft. Cold deserts exhibit a huge seasonal variation in weather – a short, dry, cloudless, arid summer reaching 36°C and a long, windy, freezing winter at −32°C. It has highly arid conditions with rainfall among the lowest in the country and bulk of the precipitation received in the form of snow. They are characterised by a fragile ecosystem with limited availability of natural resources leading to rapid resource degradation and associated environmental consequences that adversely affect indigenous communities and their livelihoods. Blizzards, snowstorms and avalanches are common in these regions.

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Unproductive soil and adverse climatic conditions allow a very short growing season. Water resources are minimal with glacier-fed streams being the only source of irrigation. With the growing tourist influx, the pressure on the environment is also increasing.

1.2 Climate change and its impacts on cold deserts

Intergovernmental Panel on Climate Change (IPCC) (1996, 2001) assessment report has indicated that the pattern of global warming will be more pronounced at high altitudes, especially in the tropics and sub-tropics (where the Himalayas is the largest range) – up to three to five times faster than in the rest of the world. The glaciers of the Himalayas account for the largest amount of snow and ice outside the polar icecaps (Dannevig, 2005). Investigations have shown an overall reduction in glaciated area from 2,077 sq. km in 1962 to 1,628 sq. km in 2007.

Climate change affects the natural resource base posing a big challenge for the indigenous population of this region, who are primarily agro-pastoralist. Although these marginal communities walk with a light carbon footprint, they have to bear the brunt of unsustainable resource use elsewhere in the world. Their adaptive capacity is low and vulnerability high, because of limited public services, little or no economic diversification, and strong dependence on a few resources. Complex terrains, remoteness and extreme weather conditions make the region and its people more vulnerable to climate change. Livelihood options are limited and poverty levels are high.

Across the Indian Himalayas severe climatic conditions, lack of market linkages, and small fragmented farms have forced the farmers to adopt subsistence farming systems (Maikhuri *et al.*, 1996; Semwal and Maikhuri, 1996; Palni *et al.*, 1998; Rao and Saxena, 1994; Ramakrishnan *et al.*, 1994; Nautiyal *et al.*, 1998, 2002-2003). The traditional methods of dealing with water scarcity have been fading away in recent years (Gupta and Tiwari, 2002).

The incidence of droughts, snowstorms, blizzards and the like has risen through the years. Recent stress on cash crops has increased soil loss and run-off from the croplands thus affecting agriculture that is the mainstay of the people here. Increase in livestock population but reduction in fodder production from farmland with changing cropping patterns implies stress on already degrading rangelands. Approximately, 70 per cent of alpine pastures are facing degradation, thus affecting the livelihoods of thousands of high altitude pastoralists.

Studies indicate a definite variation in precipitation pattern in the Himalayas. Snowfall pattern oscillates in two important ways:

(1) reductions in the amount; and
(2) changes in the timing.

There is also significant change in the amount of rainfall and increase in number of cloudy days over the years. Local perceptions further reveal that the temperature distribution has undergone a significant shift with an overall increase in temperatures. Cloudbursts and other such phenomena have increased over time (Vedwan and Rhoades, 2001).

2. Vulnerability profile of cold deserts *vis á vis* climate change

In 2006 and 2007, Pragya carried out a comprehensive study to assess the degree and nature of environmental threat in Himalayan cold deserts, as well as the Adaptation

Capacity of the region, taking watersheds as units of study. The study sought to evaluate the relationships between various geographic, ecological, climatic and socio-economic factors, and helped in understanding the nature of interactions among these. It helped in determining the vulnerability of cold desert watersheds and identifying major causal and mediating factors.

2.1 Study methodology

Field studies were carried out across two different bio-geographic zones – the Trans-Himalayas and the Western Indian Himalayas. The study area spreads across three districts of the state of Himachal Pradesh: Lahaul and Spiti, Kinnaur and Chamba, and one district in the state of Jammu and Kashmir: Leh. A stratified, nested sampling procedure was adopted and 82 watersheds selected for intensive study (Table I). Within each bio-geographic zone watersheds were delineated and categorized into four altitude bands and three hydrological levels – based on the discharge of the streams and the topographical settings (Figure 1). Other differentiators hypothesized to have an impact on the factors being assessed were aspect of slope and distance from major market hubs and administrative headquarters. A representative sample was selected based on these differentiating factors.

Bio-geographic zones	State	Districts	Watershed level	No. of watersheds surveyed
Trans-Himalayas	Jammu and Kashmir	Leh	1	8
			2	10
			3	7
Western Himalayas	Himachal Pradesh	Lahaul and Spiti	1	6
			2	24
			3	4
	Himachal Pradesh	Kinnaur, Chamba	1	6
			2	15
			3	2

Table I.
Sampling details

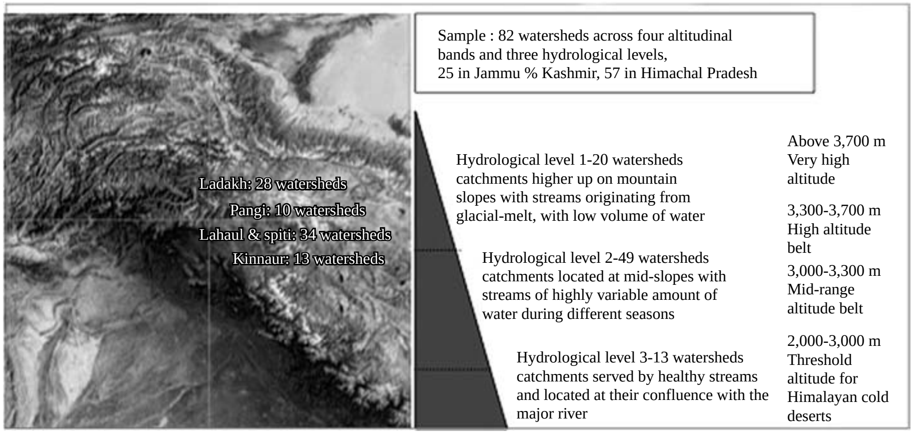

Figure 1.
Sampling distribution of the watersheds

The following kinds of data was collected:

- watershed-specific data (e.g. resources, incomes, assets, vegetation density, soil quality, hydrology);
- area/multi-watershed data (e.g. crop yields, crop value, productivity of crops/animals, perception of threat); and
- regional/district data (e.g. agricultural land, grassland, forest land, wasteland, weather records, disaster occurrence).

A participatory approach blended with scientific field observations and secondary data collection was adopted. Participatory rural appraisals were carried out in each village served by a sample watershed in order to collect primary data on socio-economic and resource-related factors, as well as to discern trends in climate, ecology and resource availability. A participative mapping and ecological study was carried out in which field surveys were conducted in each watershed using scientific measurement, with the involvement of the resident communities of the watershed. The process involved transect-walks for the mapping of resources and study of sample quadrats for a detailed study on vegetation status. Flow, depth and velocity measurements were taken, and channel shape, depositional features, etc. were studied for assessing hydrological conditions in the main stream of the catchments; water samples were collected for chemical analysis. Study of soil conditions involved observation of physical parameters and collection of samples from different habitats and land-use category in each watershed for detailed laboratory analysis. Group meetings were conducted with representatives from the villages in the watersheds and also with groups representing each administrative block to collect area data on factors that are common across a larger area including multiple watersheds to draw out regional variations.

The variables were weighted and combined through principal component analysis into sub-indices related to hydrology, soil conditions, vegetation status, available resources and infrastructure, etc. that were then further integrated into eight composite indices. These indices constituted the predictive variables for vulnerability assessment. They were:

(1) Resource status (availability of bio-resources, water, infrastructure for water storage and distribution).

(2) Ecological balance (hydrology, vegetation, soil conditions).

(3) Development status (status of health care, education, women, food security, economic capacity, access to services and support from the government and CSOs).

(4) Eco-degradation (indications of soil contamination, soil erosion, water quality, erosion of stream bank, alteration of wetlands, desertification).

(5) Anthropogenic pressure (dependence on natural resources, developmental pressure and increase in pressure).

(6) Resource stress (supply of water for drinking and irrigation, productive and unproductive resources, per capita availability of NTFPs).

(7) Disaster risk (frequency of occurrence, perception of threat).

(8) Climate change: (change in amount of snow, rainfall, availability of water resources).

Analysis of these predictive variables and the direction of their influence helped to determine the criterion variables and their component indices:

- Environmental threat: eco-degradation, anthropogenic pressure, resource stress, disaster risk, climate change.
- Adaptive capacity: resource status, ecological balance, development status.

The exercise focused on charting vulnerability hotspots of the Himalayan cold deserts, identifying the driving forces (both anthropogenic and natural processes) and consequent ecological and socio-economic impacts. The two criterion variables were used to identify the "vulnerability hotspots" while the component indices helped in depiction of the key characteristic features of the study units.

2.2 Geographic determinants of socio-ecological status

Geographic factors were found to be key determinants of the ecological health and environmental stressors affecting the cold desert watersheds under study, and correlated strongly with socio-economic status of resident communities and the anthropogenic stressors associated with this.

2.2.1 Description of socio-ecological status by altitude belt. (a) Very high altitude (> 3,700 m): Watersheds in this belt are primarily of the first and second hydrological level with moderate water availability, soil quality and vegetal growth. Per capita resource availability is moderate due to low population density in the region. However, the primarily nomadic population is highly dependent on natural resources. Resource stress experienced here is the highest of all altitude belts (74 per cent settlements facing high to very high stress). Pressure on pasturelands is high due to large herd sizes. With receding glaciers, changing snowfall patterns and rising temperatures, the high altitude plateaus are showing highest levels of climate change associated degradation, along with shrinkage of resources and frequent disasters. The environmental stress is amplified for watersheds of the first hydrological level. Watersheds of the second hydrological level are typically on steep slopes and hence more prone to natural disasters. Inhabitants of this altitude belt suffer from poor access to basic services such as communication, electricity, market facilities, etc.

(b) High altitude (3,300-3,700 m): Here, ecological balance and per capita resource status ranges from moderate to high. Majority of watersheds display good hydrological conditions and moderate soil quality and vegetal growth. However, most watersheds exhibit high levels of degradation. Cultivation is the dominant occupation and less-efficient systems of cultivation result in resource stress. Impacts of climate change are lower here than the very high altitude belt. However, steeper gradients within this altitude belt render the settlements at high risk of disasters.

(c) Mid-range altitude (3,000-3,300 m): Majority of watersheds has good hydrological conditions, moderate soil quality and good vegetal growth. The resource status is moderate to high due to presence of urban/semi-urban hubs and associated development. Degradation levels are the highest (78 per cent watersheds display high to very high degradation). Settlements here lie mostly on steep slopes or near the floodplains – locations highly vulnerable to landslides and flashfloods. Disaster risk is therefore the highest among all altitude belts. Development in the Himalayan region has tended to flow along major rivers near the flood plains. Hence, urbanization and concomitant environmental pressures are the highest in this category

of watersheds. Welfare facilities and services are by far the highest and contribute to better human development indices. Occupational diversity is more due to urbanisation, access to resources, infrastructure and services. However, food security is low due to excessive dependence on cash crops and low livestock assets.

(d) Threshold altitude (2,000-3,000 m): Here the ecological balance is moderate. Per capita resource availability is the poorest due to high population density. However, the degree of urbanisation and the visitor traffic are a trifle lower. Watersheds in this belt also display high levels of disaster risk. These watersheds have easy access to developmental infrastructure, but suffer from lower food security due to lower per capita ownership of productive resources.

2.2.2 Ecological and resource status and climatic characteristics. The ecological status of the 2,000-3,000 m altitude belt in the cold desert region is moderate, improves between 3,000-3,300 m, peaking at 3,300 m, then drops with increase in altitude in the 3,300 and 3,700 m and the > 3,700 m altitude belts. Per capita availability of resources is at the highest in the > 3,700 m altitude belt, drops steadily as population increases (with reducing altitude) to be at its lowest in the 2,000-3,000 m altitude belt. Resource stress however, is highest for the > 3,700 m altitude belt, followed by 3,000-3300 m altitude belt. The impacts of climate change is the highest above 3,700 m and at the altitude belt 3,000-3,300 m, followed by 2,000-3,000 m and 3,300-3,700 m altitude belt in intensity of impacts.

2.2.3 Socio-economic and settlement patterns. Most settlements in the area lie in the second hydrological level. The areas under the first and the third hydrological levels are often not feasible for settlement – the former because they are climatically harsh and have limited resources and development, and the latter because these areas are more prone to disasters like floods. Population density reduces with altitude but development is at its relative best in the 3,000-3,300 m altitude belt since maximum urbanisation and infrastructure and facilities are available here. The 2,000-3,000 m belt comes next in development status, followed by the > 3,700 m belt (primarily as a consequence of a better per capita resource and asset ownership) with the 3,300-3,700 m belt displaying the poorest performance in terms of development.

2.3 Causal relationships between social and ecological factors

2.3.1 Climate change and development, resource stress, disaster risk. The impacts of climate change on the high altitude cold deserts is recognised to be very high. The study findings helped bring out the associations between climate change and other social and ecological factors. The level of development was found to have a positive correlation (0.3) with the impacts of climate change, indicating areas with higher levels of development tend to score higher on the indicators of climate change, such as enhanced pressure on the hydrology, drying up of water resources and growing distance from glaciers. The nature of impacts of climate change also emerged from the study. Climate change is reducing the natural resources availability for communities, as indicated by a positive correlation (0.38) between climate change and resource stress. It is reducing the snow cover, availability of water for drinking and irrigation as well as the natural vegetation that the communities depend on. Change in climate is also found to have a concomitant change in the frequency of floods, droughts, avalanches and landslides (correlation coefficient 0.3) and hence, threaten the livelihood and property of the people living in the region.

2.3.2 Resource stress and anthropogenic pressure, climate change, resource status. Resource stress is a critical issue for these natural resource dependent communities. The study brought out a strong correlation (0.35) between anthropogenic pressure and resource stress. Population increase, development, and tourist inflow – all have an impact on the available resources and the per capita share. Overuse of resources to accommodate the increasing population is causing resource degradation and stress.

2.4 Vulnerability criteria and their predicators

2.4.1 Factor contribution to environmental threat. Analysis reveals that climate change and its close associate, disaster occurrence, together constitute the highest contributor to environmental threat (39.06 per cent) in the study region (Figure 2). Human needs and practices are deemed to be the second highest contributor (34.01 per cent). This comprises the impacts of anthropogenic pressure (15.45 per cent) on the ecosystem as a result of development and resource use practices, as well as resource stress and the increasing demand-supply gap (18.56 per cent). The natural process of environmental degradation caused by desertification, erosion, wetland alteration, etc. follows at third place.

2.4.2 Factor contribution to adaptive capacity. The ecological characteristics and health of a watershed is the largest contributor to the adaptive capacity of the watershed (Figure 3). A healthy ecological state enables the ecosystem to adapt to anthropogenic and climate induced stress, thus enabling the community dependent on it to sustain themselves. Hydrological balance (23.9 per cent) has the highest contribution in this regard followed by soil (20.96 per cent) and vegetation (16.06 per cent). Per capita resource

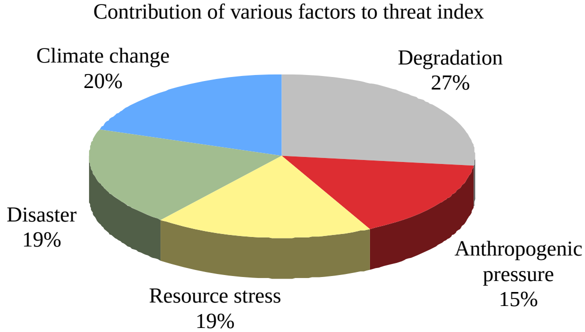

Figure 2.
Percentage contribution of various sub-indices to the threat index

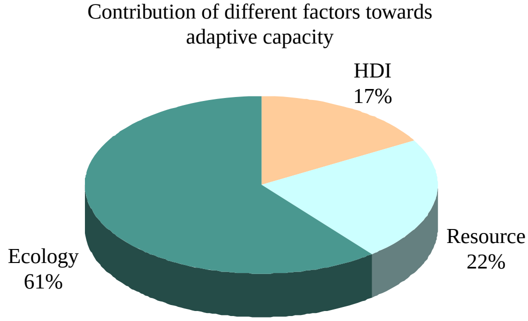

Figure 3.
Percentage contribution of various sub-indices to the adaptation index

availability is a key contributor to the adaptive capacity (22.45 per cent). The development status of the population of a watershed is also a significant contributor to the adaptive capacity of a cold desert watershed (16.62 per cent).

2.5 Threat and adaptation patterns

2.5.1 Impacts of altitude and hydrological level on environmental threat. Environmental threat levels are the highest for watersheds in the very high altitude belt (> 3,700 m) (Figure 4). More than half the watersheds experience high to very high levels of environmental threat (17 per cent experience the highest level of threat). Watersheds in the first hydrological level in this altitude belt have high to very high threat levels; watersheds in the second hydrological level have moderate to high levels of threat.

For watersheds in the high altitude belt (3,300-3,700 m), threat levels are the lowest among all altitude belts. Most watersheds at all hydrological levels in this altitude belt have low to moderate threat levels.

For the mid-range altitude (3,000-3,300 m), threat levels are moderate to high. Threat levels are low/moderate for a majority of the watersheds in the first and second hydrological levels. In the third hydrological level however, threat levels are the highest of all altitude belts and hydrological levels.

Threat levels in the threshold altitude belt (2,000-3,000 m) are similar to that of the very high altitude, with half the watersheds facing high to very high degrees of threat. Watersheds in the first and the third hydrological levels experience moderate threat levels, while those in the second hydrological level have high threat levels:

- High threat characteristics: high threat watersheds are mostly in the > 3,700 m and 2,000-3,000 m altitude belts of the cold desert region (first hydrological level in the very high altitude; second hydrological level in the threshold altitude). They are characterised by moderate to high levels of degradation and disaster risk, high anthropogenic pressure and resource stress, and high to very high impacts of climate change.
- Low threat characteristics: low threat watersheds are found in all altitude belts in the cold desert region, although predominantly in the 3,300-3,700 m (high altitude) belt. They are characterised by moderate to high levels of degradation, resource stress, disaster risk and impacts of climate change, and moderate levels of anthropogenic pressure.

2.5.2 Impacts of altitude and hydrological level on adaptive capacity. Adaptive capacity of watersheds in the very high altitude belt ranges from moderate to high, 61 per cent of

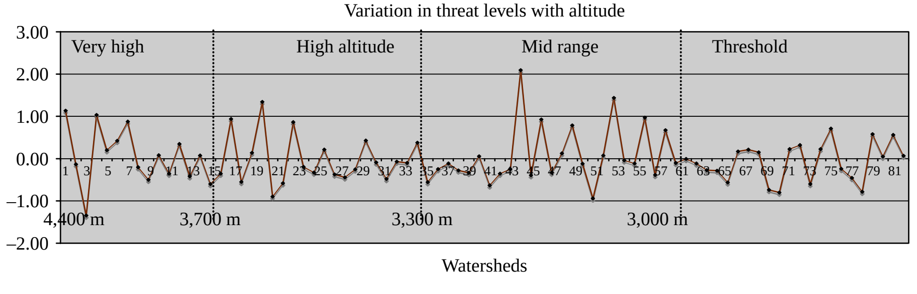

Figure 4.
Change in level of threat with altitude

the watersheds being in the low-moderate range. Higher levels of adaptive capacity are seen in watersheds in the first and second hydrological levels due to higher per capita resource availability.

In the high altitude belt, the adaptive capacity of watersheds is higher, with the highest levels found in the watersheds of third hydrological level.

In the mid-range altitude belt, adaptive capacity of watersheds increases steeply. Adaptive capacity is the highest for watersheds in this altitude belt (67 per cent watersheds having high to very high adaptive capacity); with highest adaptive capacity displayed by watersheds at the third hydrological level.

The adaptive capacity of watersheds in the threshold altitude belt is lower than that of the mid-range altitude belt. 50 per cent of the watersheds have high to very high capacity. Adaptive capacity is the lowest for watersheds in the first hydrological level in this altitude belt:

- High adaptation characteristics: watersheds with high adaptive capacity are found mostly at the 3,000-3,700 m altitude belt, comprising the mid-range altitude and the high altitude belts in the Himalayan cold deserts, and predominantly in the second hydrological level. These are characterised by high ecological balance and development status and moderate to high resource status.
- Low adaptation characteristics: watersheds with low adaptive capacity are predominantly found at $>$3,700 m (very high altitude) and 2,000-3,000 m (threshold altitude) altitude ranges and majority lie in the first and second hydrological levels. These are characterised by moderate resource status, ecological balance and moderate to low development status.

2.6 Vulnerability dynamics

Vulnerability is a measure of the dynamic interplay between environmental threat and adaptive capacity. While threat is a factor of environmental trends with effects of geographic factors in association with human interventions, adaptation is a measure of the capacity of the ecology and resource users to respond to shifts in environmental patterns with least damage to quality of ecology/life. Vulnerability of cold desert watersheds comprises the following kinds of threats:

- Threat to livelihood.
- Threat to life and/or nature of life.

2.6.1 Threat-adaptation dynamics

- High threat-high adaptation (HT-HA) watersheds are typically located in the $>$3,700 m (very high altitude) and 3,000-3,300 m (mid-range altitude) altitude belts. They are characterised by high levels of threat factors, viz degradation, anthropogenic pressure, resource stress, disaster risk and impacts of climate change. They also display moderate to high level of resources, high ecological balance and a high development status.
- High threat-low adaptation (HT-LA) watersheds are typically located in the $>$3,700 m (very high altitude) and 2,000-3,000 m (threshold altitude) altitude belts. These watersheds are characterised by moderate to high levels of degradation and disaster risk, high anthropogenic pressure, resource stress and

high impacts of climate change. They have moderate to high resource status, moderate ecological balance and a moderate level of development.

- Low threat-low adaptation (LT-LA) watersheds are found in the >3,700 m (very high altitude) and 3,300-3,700 m (high altitude) altitude belts in Himalayan cold deserts. They are characterised by moderate to high levels of degradation and resource stress, but moderate levels of anthropogenic pressure, disaster risk and impacts of climate change. Although moderate to high on resources, they tend towards moderate levels of ecological balance and development.
- Low threat-high adaptation (LT-HA) watersheds are found at all altitudes in the cold desert region, from 2,000 to 5,000 m altitude range. Their characteristics on threat factors are the same as all low threat sites. Although moderate to high on resources, they display high ecological balance and high levels of development (Figure 5).

Watersheds with high scores on environmental threat and low scores on adaptive capacity (HT-LA) are the most vulnerable, followed by those with high scores on environmental threat and adaptive capacity (HT-HA) and with low scores on environmental threat and adaptive capacity (LT-LA). The least vulnerable of all watersheds are those having low scores on environmental threat and high scores on adaptive capacity (LT-HA) (Table II).

3. Interventions to address vulnerability

The Vulnerability Hotspots of the Himalayan cold deserts may thus be determined to be the HT-LA watersheds. These are typically located in the altitude belts of 2,000-3,000 m and >3,700 m and the first and second hydrological levels. They are deemed to be severely affected by environmental stressors. This indicates the need for focused

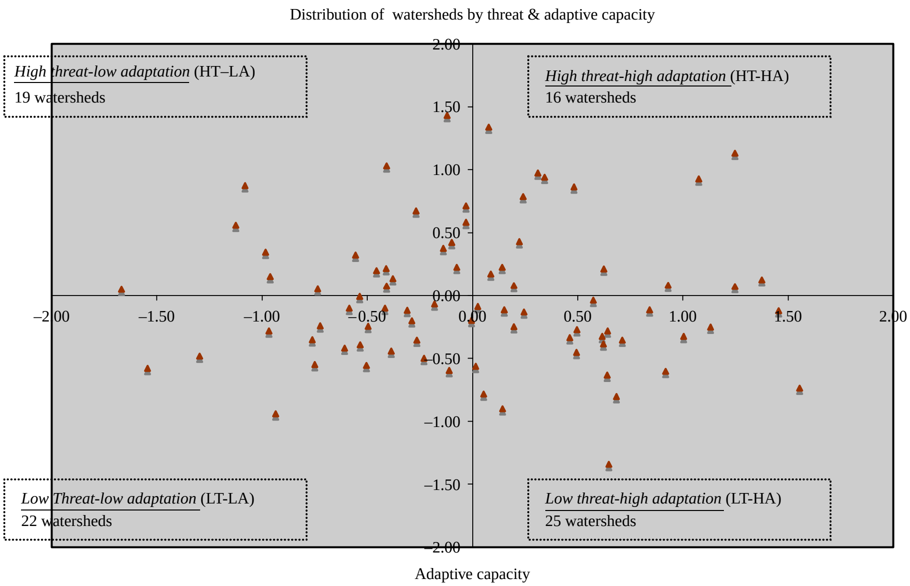

Figure 5. Distribution of watersheds according to threat and adaptation dynamics

Table II.
Characteristics of watersheds according to threat and adaptation dynamics

HT-LA > 3,700 m (very high altitude) and 2,000-3,000 m (threshold altitude) Moderate to high degradation and disaster risk High anthropogenic pressure and resource stress High impacts of climate change Moderate to high resource status Moderate ecological balance Moderate level of development	*HT-HA* > 3,700 m (very high altitude) and 3,000-3,300 m (mid-range altitude) High degradation, anthropogenic pressure, resource stress, disaster risk High impacts of climate change Moderate to high resources base High ecological balance High development status
LT-LA > 3,700 m (very high altitude) and 3,300-3,700 m (high altitude) Moderate to high degradation and resource stress Moderate anthropogenic pressure, disaster risk Moderate impacts of climate change Moderate ecological balance and development status	*LT-HA* 2,000 to 5,000 m Moderate to high on resources Moderate levels of anthropogenic pressure, disaster risk Moderate impacts of climate change High ecological balance and development levels

development interventions to address vulnerability at these specific altitude belts where such vulnerability is especially intense.

The key contributors to environmental threat and adaptive capacity can serve as the cues to the nature of interventions that may be designed to address vulnerability of cold desert watersheds. Interventions could seek to:

- Build adaptive capacity.
- Reduce environmental threat.

An appropriate weaving of transforming structures can alter the causal relationships for environmental threat as identified by the study and help address vulnerability of the region. It is imperative that an approach for equitable achievement of human and environmental development is followed, blending social justice with conservation.

We propose a two-pronged strategy for addressing vulnerability:

(1) The creation of alternatives – in livelihoods, technologies, materials, sources of supply – to address overuse/inappropriate use of natural resources.

(2) Conservation and protection – protection of the environment through positive and motivating modes, as well as through coercive controls – and protection against disasters through measures that reduce risk and mitigate impacts.

3.1 Creation of alternatives

3.1.1 Alternative livelihoods with a competitive advantage. The overuse of resources in the Himalayan cold deserts is rooted in the nature of livelihoods. The study found that occupational diversity has an association with the adaptive capacity of watershed units. Low occupational diversity is strongly related with low development status and lower or negative adaptive capacity. In 77 per cent of cases where < 10 per cent of the population is engaged in secondary and tertiary occupations, the adaptive capacity is low. Occupational diversity is higher in settlements at lower altitudes. 43 per cent and 36 per cent of the samples in very high and high altitude categories, respectively, have low occupational diversity (less than 10 per cent engaged in secondary and tertiary sectors), leaving them more dependent on natural resources. Hence, they suffer from low adaptive capacity. A prime concern is that, in all the cases where the respondents perceive a higher threat to livelihood, more than 55 per cent of the population is engaged in primary occupations. A corollary is that the level of degradation is higher in watersheds in which the majority population is engaged in primary occupations. In other words, dependence on primary occupations increases the degree of environmental threat.

A shift in occupational pattern can reduce environment threat and increase the Adaptive Capacity of the population. Alternate non-farm livelihoods would need to be introduced to ease the pressure on the natural resources. Livelihoods with a competitive advantage would enable effective "livelihood rehabilitation". Ecotourism, handicrafts and culture-based products can be some alternate livelihood avenues with a high income and employment-generating potential.

3.1.2 Alternative, high-contribution uses of natural resources. Extent of resource use is also mediated by the nature of use and its revenue yield. Hence, alternative natural resource uses that have a higher contribution in terms of incomes per unit of natural resource used could be introduced. This would help retard the trend of ever intensifying use of natural resources. Some inherent blocks to such high-contribution uses would have to be removed.

3.1.3 Value-addition to primary produce and a better share of revenues. The margins on primary produce are always low and those on value-added products higher. The natural resource intensive use/overuse syndrome could be considerably ameliorated by bringing in value-addition to local produce that would increase incomes per unit of resource used. For primary produce dependant communities, this would necessitate a move up the value chain, to include at their point, some or all processing that the primary produce undergoes before purchase by the end-user. These processes would enable retention of more margins on the final products within the Himalayan communities and enable some of the people to move out of the farm-based activities to working on or managing these processes. A likely spin-off of value-addition is the development of secondary industries. A direct access to buyers or an enhanced strength through cooperatives could also help reduce channel losses in terms of margins to intermediaries.

3.1.4 Alternate materials and technologies. The demand-supply gap in resources and the resultant overuse is a key contributor to environmental threat and a result of it as well. The cold desert communities follow traditional techniques of resource use and management such as organic cultivation that improve the ecological balance. Adoption of improved technologies, such as drip and sprinkler and lift irrigation would improve productivity of water resources and thus reduce stress. Drought-resistant crop varieties also need to be introduced in the highly water-stressed watersheds. In the context of the growing shrinkage of available natural resources for the domestic and occupational uses, alternates would need to be found for satisfying the community needs.

3.1.5 Alternatives for improved resource availability. In very high altitudes especially, threat to livelihoods is strongly connected with environmental threat. People's perception of threat levels to their present indigenous livelihoods has revealed that 41 and 43 per cent of sample watersheds in high and very high altitude levels experience a higher degree of threat. These are areas with a near total dependence on wild resources for livelihood inputs and for supplementary inputs for consumption needs as well. Apart from more efficient methods of resource use, supplementary sources of supply must be created for the NTFPs used by indigenous communities. Captive production of such NTFPs would not only reduce overuse and degradation, but also the pressure on resources and the associated insecurity in the communities. Fodder farms, seed banks, plantations for timber and fuelwood, etc. could greatly reduce this dependence on NTFPs.

3.2 Protection and conservation

3.2.1 Eco-development interventions. The study found that watersheds facing a higher degree of resource stress have a greater amount of unproductive/less productive resources. Improving the quality of these resources and sustainable utilization for better economic returns, will also improve the adaptive capacity of the watersheds. Targeted interventions for reducing erosion, improving soil quality, moisture conservation, afforestation, etc. need to be undertaken in watersheds with poor ecological balance. Wasteland reclamation needs to be undertaken using soil and water conservation techniques and planting of appropriate crops. Erosion and desertification are critical issues in the area. People should be motivated to address these through appropriate conservation and watershed development measures.

3.2.2 Provision of basic services and rights. Provision of adequate public goods and basic welfare services reduces insecurity among the recipient communities and raises the capacity of the people to access a better quality of life. For the Himalayan people, the reach of these services would enable communities to adopt the strategies for vulnerability reduction. For instance, in 83 per cent of the cases where occupational diversity is low, literacy rate is less than 50 per cent. This restricts choice of avenues that can improve their economic status and reduce dependence on natural resources. Therefore, strengthening the welfare systems needs to be a precursor to introduction of alternate livelihoods.

3.2.3 Protection against disasters. Disasters are of two kinds – slow onset (desertification) and rapid onset (flash floods and others) type. Climate change and disaster risk together are the highest contributors to environmental threat in Himalayan cold deserts. It is imperative that a comprehensive disaster management strategy is evolved and responsibilities of communities, and state and non-state agencies, drawn out, with respect to risk reduction measures as well as preparedness and response. Various conservation and protection actions can be undertaken (e.g. vegetative and structural measures – plantations and floodplain development actions, check dams, storage measures). Most of the watersheds that face a severe threat to livelihoods belong to the second hydrological level, away from major water source where water available from glacier-melt streams and springs has reduced, dried up or remain dry during the core summer months, much of agricultural land have turned waste due to crop failures. Here, water diversion and storage systems that ensure water security for the population are crucial.

3.2.4 Community governance and conservation. Communities have shown their capability to govern natural heritage by managing controlled use of larger wild areas through the use of social sanctions. Common property resources (CPRs) are relatively well administered by communities through usage norms and rights. A participative management of wild areas, along with a thrust on conservation education and activities, would help revive a sense of community stewardship. There could well be synergies between conservation and livelihood generation. Well-managed conserved spaces can be visited without destruction, and if marketed well, can generate revenues. Tourism associated revenues from nature parks is an acknowledged synergistic avenue, where the revenues flow to inhabiting communities. Similarly, artificial wetlands may be used for pisciculture, which could in turn enhance local income, while performing the normal ecological functions of wetlands.

4. Local initiatives for mitigation of climate impacts

Recognising the urgent need for ameliorating the growing impacts of climate change in the Himalayan cold deserts, Pragya, implemented a project in partnership with Whitley Fund for Nature, working primarily at the local level with communities directly affected by the issues discussed. The big lottery funded project, titled "Water Access and Wasteland Development (WAWD) in the Western Indian Himalayas", combines natural resource management strategies and infusion of appropriate technology, along with social mobilization, to mitigate the growing problems of climate change associated ecosystem stress in this region. The project area stretches across the four districts of Leh, Lahaul and Spiti, Chamba, Kinnaur in the two states of Jammu and Kashmir and Himachal Pradesh.

4.1 Disadvantages suffered by cold desert communities

4.1.1 Low incomes and subsistence existence and low QoL. The villages of the region are characterized by 63.8 per cent of marginal landholder households with an average of 0.25-0.75 ha of land. The per capita income of the target region is on average 47 per cent lower than the national average. The soil and climatic conditions allow only irrigation-aided agriculture. Most of the small landholder families have almost 50 per cent of their landholdings lying fallow due to the lack of irrigation and investment to develop it, and have to depend on pastoralism to supplement agricultural incomes. The little irrigated land is cultivated for the consumption requirement. For cash incomes, the people are dependent on seasonal road construction/maintenance, typically backbreaking physical labour. Compounded by the inadequacy of welfare facilities in the region, the poverty of especially the small and marginal farmers keeps them illiterate, malnourished, and marginalized.

4.1.2 Increasing water stress (for irrigation) and reducing yield. The total annual rainfall in these regions is usually < 50 cm and the bulk of precipitation is in the form of snow. The soil is unproductive and water resources minimal with glacier-fed streams being the only major source of water for human use. The region had developed a unique distribution system of *kuhls* (irrigation channels) and *zings* (storage reservoirs) but these traditional techniques have not been able to keep pace with increasing water inadequacy. Because the streams and springs are drying up, water has to be drawn over long distances and evaporation losses are very high. Percolation ponds have not worked due to very low water retention capacity of the soil. The water channels get silted summer and damaged by avalanches in winter. Although sowing has to be done early in summer, the glacier melt is typically inadequate and pre-sowing water is a continual battle for the farmers. The vastly -reduced glaciers in the region and the increasingly erratic and unpredictable precipitation patterns throughout the year, mean that in addition to the reduction in melt water, snow tends to melt and run-off more quickly, leaving an arid and water-less summer – the only cultivation season for local communities. The depleting water resources for irrigation are leading to reduced crop yield and impoverishment of the farmers, who are forced to abandon their fields and take to road labour in order to manage household requirements.

4.1.3 Increasing stress for potable water and consequent health issues. As a result of the decreasing snowfall and increasing environmental degradation, the natural springs catering to drinking water needs of communities are drying up. This leads to conflicts over water sharing and access. Pressure on the diminishing springs by animals and humans is polluting them thus reducing access to clean potable water and leading to occurrence of water-borne diseases.

4.1.4 Increasing desertification and conflict over CPRs. Wastelands in these cold desert watersheds amount to 77.43 per cent of the total geographical area which is in stark contrast to net cultivated area of 0.16 per cent. Only 20 per cent of the cultivated area is irrigated area and the remaining is rendered unreliable in terms of output and extremely vulnerable to droughts. The pastoralists' herds have grown by 46 per cent in the last ten years, increasing the pressure on the pasturelands. The little vegetation cover in cold deserts is being depleted because of the reducing water resources and over-exploitation (grazing by animals and wild harvesting). This has led to more desertification and wasteland creation, with increase in soil erosion and landslides. The community's dependence on these steadily depleting wild resources is leading to increasing community conflicts over usage rights.

4.1.5 Women's drudgery and low HDI. The women of cold deserts are overworked, fetching drinking water from distant water sources, collecting fuel and fodder from the wild, tending to cattle, working as agricultural and road labour at extremely low wages, attending to household chores. They spend at least 14-16 hours in a day working, and invariably tend to need the help and support of their children with the result that the girl children are forced to drop out of school and assist their mothers. Their hardship is reflected in their ill health and untimely deaths most often caused by poor nutrition, lack of access to medical care and prolonged exposure to indoor air pollution from wood-based cooking. The receding forests and depletion of water resources mean that the women have to spend more time collecting water, fodder and wood and trudge longer distances of 8-10 km up steep gradients carrying loads of up to 20 kg on their backs.

4.1.6 Recurrent environmental threats and consequent food/livelihood insecurity. These cold desert communities are also increasingly impacted by environmental calamities. Droughts are becoming increasingly frequent and the region has also witnessed devastating floods in the past causing large-scale damage to habitations, crops and livestock. For instance, Shansha village in Lahaul suffer from flood damage almost every year, which implies an expenditure of Rs. 45,000-50,000/-.

4.2 WAWD interventions

The WAWD project is concerned with both the supply and the uses of water, and aims to institute integrated water management at a watershed level. Initiated in 2006, the project has involved a comprehensive hydrology study and the assessment and testing of appropriate technologies for water (conservation, irrigation, drinking), sanitation and wasteland reclamation in Himalayan cold deserts, thus developing a package of best-fit technologies for the region. Interventions have included working with cold desert communities, with a focus on women and small and marginal farmers that are severely affected by increasing desertification and depleting glacier resources. The initiative strives to ensure that cold desert mountain communities have access to potable water, cultivable land and pasturelands of higher productivity through technical interventions, enhanced income through diversified agricultural options, and effectively managed CPRs and reduced vulnerability to environmental shocks. It also strives to reduce the drudgery of mountain women and increase their involvement in participatory management and decision making.

4.2.1 Water conservation and management. Communities in cold desert villages have been trained on water sharing and budgeting, conservation and management. Women-led Domestic Water and Sanitation Committees (DWSC) have been constituted and these have taken up the task of improving access to and management of water and addressing sanitation needs of the village.

4.2.1.a Potable water: source protection and revitalization. The dwindling springs are being revitalized through a series of measures. The process began with a participatory mapping of the springs and their feeding grounds as well as underground acquifers, drawing on knowledge of village elders. A multi-pronged revitalisation strategy was implemented for each spring and included: afforesting the slopes above the outlet with native trees, shrubs and herbs, constructing trenches and bunds on slopes higher up and installation of infiltration pits and trenches still higher up. All of these measures enhance snow accumulation and reduce runoff of the snowmelt, promoting infiltration into and recharge of acquifers thus enhancing spring flow. To maintain quality of water, the area around each spring was fenced to stop trespassing by animals that pollute the mouth of the spring. Native, herbaceous species with strong soil binding characteristics were also planted around the spring, in order to counter slippage of the moist soil and thus closure of the spring mouth.

Recharged spring in Sakling. Residents of the village of Sakling (3,755 m, district Lahaul and Spiti) are dependent on a spring for their drinking water needs situated 2 km above the village. Reduced flows as a result of general desertification in the region was a cause of concern for the villagers; moreover cattle grazing near the mouth of the spring was also leading to impure water and soil slippage. Under the WAWD project, the DWSC of Sakling village has constructed 20 snow pits (Plate 1) of the size of 4 ft × 3 ft × 3 ft just above the spring site, for improving infiltration and recharge of the acquifers feeding the spring and the spring has been fenced (Plate 2). Women of Sakling have reported a significant improvement in the spring flows since the intervention.

4.2.1.b Household water harvesting. The DWSCs have worked to identify and address the needs of household clusters affected by the reducing water flows. Pipelines and channels have been laid for improving access to distant sources of water (Plate 3), and storage tanks have been set up. Wherever groundwater is being accessed, infiltration pits are being created for recharge.

4.2.2 Wasteland reclamation and anti-desertification measures. 4.2.2.a Wasteland plantations and irrigation technologies. Small and marginal farmers have been formed into combines and assisted to bring fallow lands under cultivation through installation of appropriate irrigation technologies, such as poly-lined channels and storage tanks. Particularly water-starved villages have been aided to set up larger irrigation installations to enable them to reclaim wastelands. Technologies adopted have included snow reservoirs for harvesting snow and solar pumps for lift irrigation.

Plate 1.
Community participation for construction of snow pits in Sakling, Himachal Pradesh, India

Plate 2.
Community participation for spring fencing in Sakling

Snow reservoir in Demul. Demul village (4,269 m, district Lahaul and Spiti) is located atop a ridge (Plate 4) with an undulating topography, sparse vegetation and an inhospitable climate (winter temperatures that go down to $-30°C$). The 65 village households grow subsistence crops and also depend on pastoralism. The only source for irrigation is the snowmelt that is drawn to the fields through earthen channels. 40 per cent of the village land was assessed to be wasteland due to lack of water for irrigation.

Pragya constructed a snow reservoir for the community to enable them to harvest the abundant snowfall in and around the village during winters and harness it for agricultural purposes in the summer (Plate 5). The reservoir is at a distance of 2 km from the village at an elevation of 4,389 m. The bed of the site is plain and flat, with a gentle slope towards the village, and a wall has been erected on this end, allowing for easy accumulation. The reservoir wall is 59 m long, 2.5 m wide and 2.5 m high.

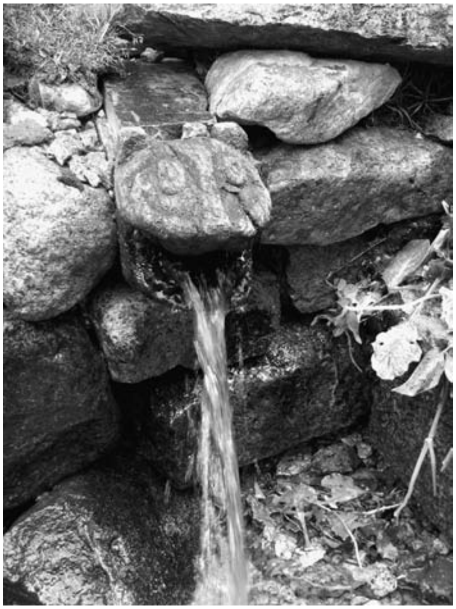

Plate 3. Spring outlet in Chitkul village, Himachal Pradesh, India

Plate 4. View of Demul village, Himachal Pradesh, India

The reservoir will help irrigate ˜1 sq. km of agricultural land and more than 100 people will benefit from it. The scarcity of water for irrigation is ameliorated to the extent of 70 per cent. The long-term benefit of the reservoir is acquifer recharge.

Solar pump in Chuchot and Umla. Chuchot, the largest high altitude village on Ladakh plateau, has vast tracts of barren land. A community-owned wasteland plot was selected for conversion to agricultural use. The irrigation technology selected for the purpose was a solar pump to lift subsurface water. The pump has a dynamic head of 170 ft, a solar panel array of 1,200 watts and a DC motor, powered by 16 solar

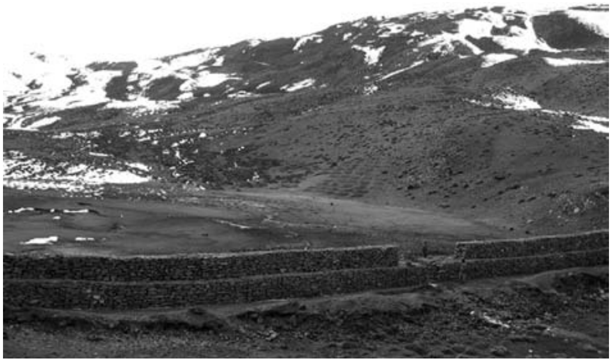

Plate 5.
Site of Snow Reservoir in Demul village

photovoltaic modules of 75 watts each. The multi-stage centrifugal pump with a capacity of 7,000 litres per day is being used to irrigate 1.06 ha of land of Chuchot Gongma and also to provide drinking water to the cold desert neighborhood in the freezing winter months. The intervention is benefiting 72 households in the village.

Umla is another small high altitude village in Ladakh that has been provided with another solar pump. A small stream passing through the village, barely meets the requirement of the village before it loses its way in the barren rocky terrain. A submersible pump with a capacity of 900 watts/3,000 litre a day has been installed with 12 PV arrays of 75 watts each.

4.2.2.b Soil and moisture conservation. Snow harvesting techniques such as snow fences, trenches and pits are also being used at many sites that have turned from cultivable lands to parched wastelands to increase the soil moisture content to become suitable for cultivation or grazing.

Snow fences in Kardang. This is a particularly arid and windy stretch of Lahaul valley. Above the village, there exists a large depression that is an effective spot for snow accumulation. Because the very high wind velocities do not allow the snow to settle on the ground, the technology of snow fences was adopted to accumulate snow. Snow fences 8.5 ft high have been installed along the side of the depression to a length of 100 ft and a gabion wall has been constructed at its lower end. The installation helps catch blowing snow and compact the settled snow, also prolonging its period of melting (Plate 6).

4.2.2.c Watershed development and drought management. The project is also setting up seed banks and local credit systems to help farmers recover from droughts. Watershed committees are being trained in various watershed development techniques, and provided extension services to access required support from the government and technology providers.

4.2.3 CPR management. Women's CPR management (CPRM) groups have been created and trained in conservation and rotational use of CPRs and revitalization techniques. They are being facilitated to establish fodder farms, plantations of energy crops, and kitchen gardens, to supplement their use of wild resources, and thus reduce pressure on them. Pastoralist combines have been formed and are being assisted to undertake pastureland restoration activities. The project is also catalyzing the development of norms and processes for careful use and equitable distribution of CPRs among households and also between villages sharing the same CPR.

Plate 6. Snow fences in Kardang village, Himachal Pradesh, India

5. Conclusion

The Himalayan cold deserts are among the most critically affected by severe impacts of climate change, and the lives and livelihoods of its communities are at risk. These areas have been unfortunate to have received very little development attention, in spite of their increasing vulnerability. Most policies and funds tend to flow to the most visible hotspots, and the extreme remoteness of the region obstructs it from grabbing attention. There is a clear need for acknowledging the Himalayan cold deserts as urgently requiring attention and ensuring a flow of resources and interventions at global and national levels, and a special place in the climate change policy-space. It also requires the delivery of a package of solutions that recognizes the inalienable right of cold desert communities for a secure and equitable life while protecting the ecological integrity of a region that is highly vulnerable.

Field studies have indicated that Vulnerability Hotspots of the Himalayan cold deserts are typically located in the altitude belts of 2,000-3,000 m and $>$ 3,700 m and the first and second hydrological levels. These watersheds are severely affected by environmental stressors without the leavening factors that contribute towards the adaptive capacity of the ecology and human population to these stressors. This stresses on the need for focussing development interventions to address vulnerability at these specific altitude belts. Interventions could seek to:

- build adaptive capacity; and/or
- reduce environmental threat.

An appropriate weaving of interventions can alter the causal relationships for environmental threats and help address vulnerability of the watersheds. The approach should have an appropriate blend of social justice and conservation priorities for sustainable human and environmental development.

A two-pronged strategy has been suggested and tested through pilot local initiatives in the target area. This includes:

(1) *Creation of alternatives* – developing alternative livelihoods that the cold deserts have a competitive advantage in, promoting more productive uses of natural resources, value-addition to primary produce that enhance revenues per

unit of natural resources, use of alternate materials/technologies that make for resource efficiency/replacement, and creation of supplementary sources for supply of natural resources through methods such as captive production.

(2) *Protection and conservation*- eco-development interventions that improve the local ecology, improving welfare of local communities through provision of basic services and rights that enables them for non-'resource intensive' activities, protecting against disasters (both rapid-onset and slow-onset), and facilitating community-based conservation and governance.

The local initiatives have had significant human and ecological benefits and need to be replicated. The findings of the study and pilot interventions may also act as guidelines for upstream actions and appropriate policies for addressing the vulnerable cold deserts.

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