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PREFACE

In this paper environmental risks are perceived in terms of circumstances that disrupt the basic biophysical processes, material and energy flows, etc; which in the ultimate analysis determine the health, productivity, and stability of environmental resources - land, water, vegetation - and their interactions in the mountain ecosystem. Interactions among the imperatives of mountain characteristics such as inaccessibility, fragility, marginality, diversity, on the one hand, and varying degrees of human interference, on the other, give rise to the above circumstances. The paper discusses the role and consequences of human interventions during low and high resource use intensification phases and attempts to see them in the global environmental changes, including the uncertain impacts of global warming.

The paper forms a chapter in a forthcoming (1992) United Nations University sponsored volume entitled Global Environmental Risk, J.X. Kasperson and R.E. Kasperson (eds).

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I. INTRODUCTION

Global environmental change is a major issue today. However, due to rather skewed perspectives relating to the work and debate on the subject (a result of overemphasis on "systemic" types of change as against "cumulative" changes), the totality of the global environmental change - its processes, consequences, and possible remedial measures - are inadequately understood and addressed. Annex Table 1 summarises some of the relevant details in this respect. In view of the greater certainty of issues involved and their regional disaggregation, a discussion focussed on "cumulative" types of global change can prove very useful. Furthermore, to fully capture the cumulative types of change, regions can be identified with ecosystems (e.g., mountain ecosystem) in the context of which man nature interactions and their consequences can be understood more easily.

The preceding issues form the background to the discussion on environmental risks in mountain areas in the context of global environmental changes. The emphasis is on understanding and handling environmental risks in the mountains, which are affected both by specific features of mountain habitats and the way the imperatives of these features are ignored or considered by human interventions in mountain areas. The discussion draws upon earlier works related to the subject (Jodha 1990a, 1990b. and 1990c).

The paper focusses on the aspects discussed below.

a) Of the two types of global environmental change, namely, (i) "systemic" change and (ii) "cumulative" change (Turner et al. 1990), the latter forms the broad context for present discussion. The former is covered only in a limited way because of the lack of sufficient information and uncertainties associated with the predicted changes.

b) Environmental risks are perceived in terms of circumstances that disrupt the basic biophysical processes and natural flows which, in the ultimate analysis, determine the health, productivity, and stability of environmental resources - land, water, vegetation, etc - and their interaction, in a given ecosystem.

c) The paper discusses environmental risk in the context of mountain areas where interactions between imperatives of specific mountain conditions such as inaccessibility, fragility, diversity, etc, on the one hand, and varying degrees of human interference on the other, constitute the circumstances that influence the biophysical processes and natural flows.

d) The geographical context of the discussion is the mountain region of the Hindu Kush-Himalayas. The paper does refer to other mountain systems, such as the Andes, to a limited extent. Within the mountain regions, agriculture (including all land-based activities such as cropping, livestock, forestry, and horticulture) is used as a focal point. This is because of both the predominance of this activity in the mountains, and to the recognition of the fact that the important environmental degradation/rehabilitation issues in most cases relate to agricultural resource use.

'Systemic' and 'Cumulative' Changes

In order to get an idea of these two types of change, we can take the lead from some recent conceptual work on the subject. Turner et al. (1990) discuss two dimensions of global environmental changes: (i) 'systemic' change and (ii) 'cumulative' change. Broadly speaking, systemic change is one which, while taking place in one locale, can affect change in the system elsewhere. The underlying activity need not be widespread or global in scale, but its potential impact is global in the sense that it influences the operation and functioning of the whole system as manifested through the subsequent adjustments in the system; CO_2 emissions from limited activities that have impacts on the great geosphere - biosphere system of the earth and cause global warming is a prime example. The cumulative types of change refer to localised but widely replicated activities where a change in one place does not effect changes in other places. When accumulated, they may acquire the scale and potential to influence the global situation in specific ways. Widespread deforestation and extractive land use practices and their potential impacts on the global environment serve as examples. Both types of change are the products of nature-man interactions and are linked to each other in several ways.

This brief introduction to the important concepts may appear sketchy but are sufficient for our purpose. Emphasis on one or the other type of change (along with the relative focus on geocentric perspectives or anthropocentric perspectives) in the work on global changes will have very different implications. These are briefly summarised under Annex Table 1 and the paper directly or indirectly illustrates some of them.

Environmental Parameters

Environment, unless expressed in terms of its vectors (or contributing factors or resources), is a product of several interactive processes of different components of a system (e.g., a mountain ecosystem). The interactive processes between living and non-living things (such as soil, water, vegetation, and animals) generate products and services that act both as inputs into the continuity and performance of the system and its output. Hence, for practical purposes, it is often difficult to separate "environment as services and products" from "environment as manifested by the status of the resources" that generate the services and products. In other words, separating the conditions generated by interactions of soil, water, vegetation, etc from the status of these resources themselves is quite difficult. However, the overall dynamics or pace and pattern of interactive processes of the resources is affected by specific attributes of the latter and the way these attributes are manipulated while using the resources. This provides evidence to say that human intervention is one of the crucial components in the environmental matrix of an ecosystem.

The contributions of interactive processes to the stability and sustainability of the environment (both as inputs and products of an ecosystem) take place through the crucial biophysical functions and flows which are quite interrelated and often invisible. They could be categoried as **"regeneration"**, **"variability-flexibility"**, **"resilience"**, **"natural cycles"**, or **"energy and material flows"**. These biophysical functions and flows (to be elaborated later) are the basic mechanisms through which the level and performance of environmental services (e.g., productivity), as well as the health and status of environmental resources of a system, are ultimately determined. These scientifically well-recognised processes are often not readily visible but their operation can be perceived through an understanding of more easily visible, measurable or verifiable circumstances.

In light of the above, the environmental risks of a system (e.g., a mountain ecosystem) can be understood in terms of instability or destruction of (i) natural resources, (ii) their productivity potential, and (iii) the processes represented by the biophysical functions and flows stated above. The environmental risks can be characterised and identified with reference to a negative change in any of the three categories of variables mentioned above. However, because of the ultimate analysis, the extent and nature of environmental risk will relate to the disruption of the last category of the above variables and the biophysical functions and flows. This is elaborated with reference to mountain areas in the present paper. However, because of the complexity and direct invisibility of most of these functions and flows, the focus of the discussion will be on more easily understood and visible circumstances that influence them.

Accordingly, first, we describe the objective circumstances, i.e., specific conditions of mountains and their likely impacts on the above functions and flows in a relatively undisturbed situation. This is followed by a discussion of changes through human interventions, under relatively low pressure on resources as manifested by traditional resource use systems in mountain areas. The next stage is characterised by increased resource use intensification, following the high pressure on mountain resources generated by increased population, accentuated market demands, and State interventions. The processes at this stage represent some dimensions of the cumulative types of global environmental change mentioned above. The discussion reveals the degree of mismatch between the imperatives of mountain characteristics and certain attributes of resource-intensification strategies as the key source of environmental risks in mountain areas. These risks are quite severe even without considering the systemic types of environmental change. They tend to make mountain areas and people more vulnerable to the potential risks of systemic changes induced by global warming.

Biophysical Functions and Flows

Since environmental risks in the mountains are discussed primarily with reference to the biophysical functions and flows stated above, an explaination of this choice is essential. Taking the lead from the understanding provided by ecological sciences and the descriptive and operational categories or terms used by them (NRC 1986, Conway 1985, Monasterio et al. 1985, Lowrance et al. 1984, Shutain and Chunru 1988, and Krutilla 1979), we try to understand the stability of mountain environments (i.e., absence of environmental risk) in terms of normal functioning of the interrelated processes such as regeneration, the system's internal variability and flexibility, resilience, natural flows, etc. Regeneration, involving processes of germination, growth, decay, decomposition, re-emergence, etc, using photosynthetic and other mechanisms supported by nature's energy and material flows, is one important condition associated with the environmental health of a system. The process of regeneration and the ability of a system to withstand stress are facilitated by the internal variability of the system where input needs and output flows of different components (e.g., annual and perennial plants) are organically interlinked. The system's internal variability, involving organisms and mechanisms with temporally and spatially non-covariate input demand and output performance, offers a degree of flexibility to the system to adjust to different perturbations. Quite related to the above are the visible or non-visible flows and cycles involving energy, moisture, and nutrients of different types and sources. Nature's pattern of energy and material flows and their balancing in the context of a system, links the components from geosphere, biosphere, etc, and helps in sustaining the health and productivity of a system. The operation of the above basic functions and flows, as mentioned earlier, is affected by the state of the natural resources, i.e., its status structure and usage pattern. For instance, a system based on diversified vegetation would be more conducive to regeneration processes and smooth functioning of natural flows. A similar case may be the practice of zero tillage on fragile mountain slopes or systematic crop rotations and the indigenous agro-forestry practices followed in mountain areas. Any practice disturbing the above arrangements may disrupt the underlying biophysical functions and flows and initiate the process of environmental instability and risk.

The important reasons for focussing on these biophysical-chemical processes and flows, rather than on simple categories of resources, such as forest, water, soil, and their product or service flows, to understand the environmental risks in the mountains are as discussed below.

In the overall context of environmental stability, sustainability, and productivity, it is the understanding of the dynamics of underlying processes and flows rather than the structure of environmental resources (represented by composition and types of resource) that can help evolve strategies to minimise environmental risks in mountain regions. An understanding of the above processes and their associated conditions can help to identify alternative resource structures, usage patterns, and their alterations to meet changing demands. For instance, in view of the unavoidable intensification of resource use in the mountains to meet the growing demands, restoration of the traditional resource-extensive management practices as well as the structure and pattern of natural resources (such as the extent and composition of forests) may not be feasible. However, by using the rationale behind traditional systems, it may be possible to evolve new resource-intensive systems that are compatible with new demands and conducive to resource conservation and the uninterrupted operation of underlying biophysical functions and flows. For instance, balancing intensive and extensive land uses by putting some proportions of an area under crops and retaining large parts under forests may not be possible. However, for the smooth operation of certain biophysical functions and flows, the key factor is the complementarity of annuals and perennials rather than the rigid proportions of specific land use categories. The aforesaid complementarity facilitated through specific proportions of intensive and extensive land use categories can be partly ensured by interplanting annuals and woody perennials, as under agro-forestry systems. Similarly, reforestation using traditional species involving a felling cycle of, say, 100 years may not be feasible today, but reforestation using early maturing trees, especially those with multiple functions, can be promoted. Thus, in the micro-level context of a degraded watershed, the focus of interventions need not be on re-creation of its past, but on its rehabilitation using the rationale behind its past status. This, in turn, implies emphasis on the dynamic biophysical processes and flows (regeneration, system's internal variability, etc) using the new leads and understanding offered by modern science and technology blended with the rationale of traditional resource management systems (Jodha 1991).

Another reason for emphasising the basic biophysical functions and flows as the focal point for understanding environmental risks is because the environment (whatever way it is defined) is an integrated product of several processes. Such processes cannot be properly addressed by focussing on individual environmental resources or their productivity. Any approach addressed to them usually acquires sectoral character and misses the required integrated focus. For instance, any strategy directed towards the stability of the hydrological cycle in a mountain region or vegetative regeneration of a mountain slope, will require the integrated use of multiple components affecting the biophysical processes and flows, rather than the application of a single component (such as reforestation) directed to achieve the same goal. Finally, for an integrated understanding of mountain characteristics, human interventions, and their risk implications, the biophysical functions and flows (rather than environmental resources) offer a more useful and effective context. This will become clear later (Tables 1 to 3).

Mountain Specificities

Since smooth operation or disruption of the above-stated biophysical processes is largely a product of specific attributes of a system (i.e., mountains), and the way in which they are treated while using their the natural resources, it is essential to briefly disgress into a discussion of relevant mountain characteristics and their risk imperatives in terms of the above-mentioned biophysical processes.

The important conditions characterising mountain areas which, for operational purposes, separate mountain habitats from other areas, are called here 'mountain specificities'. Six important mountain specificities (some of which might be shared by other areas such as deserts) are considered here. The first four, namely, inaccessibility, fragility, marginality, and diversity or heterogeneity, are called first order specificities. Natural suitabilities or 'niche' (i.e., activities/products in which mountains have comparative advantages over the plains) and 'human adaptation mechanisms' in mountain habitats are second order specificities. The latter are different from the former in the sense that they are responses or adaptations to first order specificities. But nevertheless, they are specific to mountains (Jodha 1990a).

Before describing the major mountain 'specificities', it should be noted that these characteristics are not only interrelated in several ways but, within the mountains, they show considerable variability. For instance, all locations in mountain areas are not equally inaccessible, fragile, or marginal. Neither do human adaptation mechanisms have uniform patterns in all mountain habitats. With full recognition of such realities we can briefly introduce the mountain specificities.

Inaccessibility

Owing to slope, altitude, overall terrain conditions, and periodic seasonal hazards (e.g., landslides, snow, storms, etc), inaccessibility is the best known feature of mountain areas (Price 1981, Allan 1986, and Hewitt 1988). Its concrete manifestations are isolation, distance, poor communications, and limited mobility. Besides being the dominant physical dimension, it has sociocultural and economic dimensions (Jodha 1990a). The implications of inaccessibility as objective circumstances, influencing the operation of biophysical functions and flows can be justified as follows. Firstly, it restricts the mobility and external linkage-related disturbance to the ecosystem. Secondly, the relative closedness of the mountain habitat imposes a number of compulsions for linking survival strategies to the local availability of resources, and their protection and regeneration. Thirdly, meeting diversified human needs in a closed or isolated situation induces diversification in production and resource use patterns, both in temporal and spatial contexts. Fourthly, the limited scope for dependable external linkages and supplies induces adjusting demands to supplies (rather than the other way round) through various forms of demand rationing and periodical syphoning of pressure through transhumance and outmigration. The coping strategies stated above are potentially more conducive to biophysical processes essential for environmental stability.

However, a disregard of the above imperatives, for any reason, can make mountain areas and mountain people vulnerable to serious environmental risks. For instance, increased internal pressure on resources through population growth within a relatively closed system may lead to over-exploitation of resources and reduced diversification and flexibility of resource use patterns. Similarly, the establishment of external linkages within the overall context of the general inaccessibility problem may accentuate selective resource extraction and external exchange on unequal terms. Such developments may generate circumstances that are less conducive to environmental stability of the mountain regions. Tables 1 to 4 indicate some of the relevant issues mentioned above.

Fragility

Because of altitude and steep slopes in association with geological, edaphic, and biotic factors that limit the former's capacity to withstand even a small degree of disturbance, mountain areas are known for their fragility (DESFIL 1988). Vulnerability to irreversible damages, caused by overuse or rapid changes, characterising the land, vegetative resources, and even the delicate economic life-support systems of mountain communities, is manifested by limited options. Consequently, mountain resources and environment deteriorate rapidly and sometimes irreversibly due to disturbances (Eckholm 1975 and Hewitt 1988). Environmental risks related to fragility will be commented on shortly.

Marginality

A 'marginal' entity (in any context) is one that counts the least in the context of a 'mainstream' situation. This may apply to physical and biological resources or conditions as well as to people and their sustenance systems. The basic factors contributing to such a status of any area or community are remoteness and physical isolation, fragile and low-productivity resources, and several man-made handicaps which prevent one's participation in the 'mainstream' pattern of activities (Blaikie and Brookfield 1987 and Chambers 1987). The mountain regions, being marginal areas in most cases, share the above attributes of marginal entities and suffer the consequences of such a status in different ways (Jodha 1990b). To this may also be added that 'marginality' implies a comparative context (i.e., a situation, an option, a resource, an area, or a community) and has a marginal status in comparison to other entities of the same genre. Accordingly, an entity acquires marginal status when compared or linked with other entities. There are several examples of mountain areas, their production systems, and people's adaptation strategies, becoming marginalised and, therefore, unequal, through their integration with dominant, mainstream situations in the plains.

Although products of broadly different factors and processes, marginality and fragility characteristics share a number of common risk implications. Accordingly, unless the resources are upgraded or strengthened, the existing use capacity and input absorption capacity of fragile and marginal resources remain low. They are suited for less intensive uses with low productivity and low pay-off. These features, in turn, restrict the scope for diversification and flexibility, and reduce the system's (physical and economic) abilities to absorb shocks, making it vulnerable to different sources of risk. The risks become a reality when increased pressure on resources (caused by population growth, etc) or the side effects of external linkages and interventions, push their usage level far beyond their use capabilities.

Diversity or Heterogeneity

In mountain areas, one finds immense variations among and within ecozones, even within short distances. This extreme degree of heterogeneity in the mountains is a function of interactions of different factors such as elevation, altitude, geological and edaphic conditions, steepness and orientation of slopes, wind and precipitation, mountain mass, relief of terrain, etc (Troll 1988). The biological adaptations (Dahlberg 1987) and socioeconomic responses to the above diversities also acquire a measure of heterogeneity of their own (Price 1981 and Jochim 1981). The diversity or 'heterogeneity' phenomenon applies to all mountain characteristics discussed here. From the view point of environmental risk, internal diversity of mountains is the most important factor that helps in the smooth operation of biophysical processes and flows and thereby ensures environmental stability. This is both a basis for diversified, interlinked activities and a source of resilience for people's survival strategies in the mountains. However, the imperatives of diversity in terms of matching diversification in resource use and production practices can be used as a basis for interventions in the mountains only if the human demands are also diversified. These imperatives may be ignored with reduced diversity of demands on mountain resources. This may happen because of increased population and consequent changes in resource use patterns focussing on staple foods rather than on diversified products. Similarly, market-induced narrow specialisations can reduce diversification. Such changes can prove detrimental to the environmental stability associated with the internal diversity of mountain ecosystems.

'Niche' or Comparative Advantage

Owing to their specific environmental and resource-related features, mountains provide a 'niche' for specific activities or products or services. At the operational level, mountains may have comparative advantages over the plains in these respects. Examples include mountains serving as the habitat for specific medicinal plants, as a sources of unique products (e.g., some fruits, flowers, etc), and as the best known sources of hydropower production. In practice, however, 'niche' or comparative advantages may remain dormant unless circumstances are created to harness them. However, mountains, owing to their heterogeneity, have several specific 'niche', which are used by local communities in the course of their diversified activities (Whiteman 1988 and Brush 1988).

A 'niche' is a product of interactions of various biophysical (and even socioeconomic) factors. Their regulated use and protection are conducive to the environmental health of a region. Since a 'niche' in a way is a part of the diversity characterising mountain habitats, its environmental risk implications are also similar to those of 'diversity' as discussed above. Its role in the circumstances affecting basic determinants of environmental stability (i.e., regeneration, resilience, energy and material flows, etc) is affected by the pace and pattern of extraction of the 'niche'. Over-exploitation of 'niche' (e.g., timber or hydropower potential) and disregard of the side effects of extraction methods can adversely affect the environmental situation. Evidence shows that both State interventions and market forces tend to contribute to over-extraction of 'niche' and thereby affect the environmental stability of mountains.

Human Adaptation Mechanisms

Mountains, through their heterogeneity and diversity, even at the micro level, offer complex constraints and opportunities. Mountain communities, through trial and error over the generations, have evolved their own adaptation mechanisms to manage them (Guillet 1983 and Jochim 1981). Accordingly, either mountain characteristics are modified (e.g., through terracing and irrigation) to suit their needs, or the activities are designed to adjust the requirements to mountain conditions (e.g., by zone-specific combinations of activities, crops, etc). Adaptation mechanisms are reflected through formal and informal arrangements for resource management, diversified and interlinked activities to harness micro-'niche' of specific eco-zones, and effective use of upland-lowland linkages (Allan 1986, Brush 1988, and Whiteman 1988). Adaptation mechanisms helped in the sustainable use of mountain resources and stability of mountain environments in the past. However, with the changes related to population, market, and public interventions, a number of adaptation mechanisms are losing their feasibility and efficacy. It may be noted that understanding their rationale can help in the search for options to reduce emerging environmental risks in the mountains. This will be elaborated upon later.

II. MOUNTAIN REGIONS : NATURAL CONDITIONS AND RISK POTENTIAL

In this section, we comment on the circumstances created by the above-mentioned mountain specificities with reference to their potential role in enhancing or obstructing biophysical processes (regeneration, flexibility, resilience, energy, and material flows) in mountain ecosystems. This essentially recapitulates the natural circumstances in mountains discussed in the preceding pages. Relevant details are summarised in Table 1. Accordingly, inaccessibility, diversity, and 'niche' create circumstances that are largely conducive to the operation of biophysical processes and natural flows. Fragility and marginality, on the other hand, create circumstances less conducive to these processes.

Table 1: Mountain Specificities and Their Environmental Stability/Risk Imperatives

Mountain specificities & their implications[a]	Risk reducing/stability promoting biophysical processes and flows			
	Regeneration	Variability /flexibility	Resilience	Energy/material flows
Inaccessibility (Isolation, limited mobility, limited external linkages, lesser disturbance to system, local resource-based diversification)	(+)[b]	(+)	(+)	(+)
Fragility (Vulnerable to degradation through small disturbance and use intensity, slow recovery, limited and low productivity options)	(-)[b]	(-)	(-)	(-)
Marginality (Limited, low potential, inferior options, vulnerable to shocks)	(-)	(-)	(-)	(-)
Diversity (Basis for diversified, interlinked activities, organic integration of potential options)	(+)	(+)	(+)	(+)
'Niche' (Products, resources, activities with comparative advantages for the mountains, result of diversity and specific resource conditions)	(+)	(+)	(+)	(+)

a) 'Human Adaptation Mechanisms' is another mountain specificity elaborated in the text. Its role in promoting environmental stability is sketched under Table 2.

b) (+) and (-) indicate respectively more favourable and less favourable circumstances generated by mountain specificities for the operation of biophysical processes and flows.

To elaborate, inaccessibility by restricting mobility, and limiting external linkages, helps reduce disturbances and perturbations to the basic biophysical processes. Similarly, diversity (internal heterogeneity) and specific 'niche' characterising the mountains also help in regeneration, in interlinkages between different living and non-living components of the system, and also facilitate intra-system flows of energy, nutrients, moisture, etc. In contrast, fragility and marginality, indicating vulnerability to resource degradation and slow pace of recovery and growth, offer limited scope for above biophysical processes and flows.

Thus, under their natural state, mountains have a mix of more favourable and less favourable circumstances affecting the operation of dynamic processes underlying the health and stability of the mountain environment. Depending on which circumstances (e.g., steep slopes with thin top soil or valley bottoms with rich soil, plentiful moisture, and diverse vegetation) dominate a given area, the risk potential for a mountain environment can be assessed.

Furthermore, as a part of the natural withering, stabilisation, and succession processes, especially in a young mountain system like the Himalayas, the above-mentioned circumstances and their environmental impacts do change (Thompson et al. 1986). However, the role of the natural processes is accentuated by human interventions (Ives and Messerli 1989). Hence, the latter plays a crucial role in altering the circumstances (indicated by Table 1) and their environmental impacts. This forms the subject of the following sections. In connection with the human interventions, an important feature of mountain specificities as elaborated elsewhere should be noted (Jodha 1990b). Most of the mountain characteristics are interrelated with each other because of their common cause or shared consequences in terms of disturbance to the one affecting the others too. The environmental risk or stability implications of these interrelationships of mountain characteristics, in terms of impacts on biophysical processes and flows, become more clear in the context of increased resource use intensification in the mountains to be discussed later.

III. HUMAN INTERVENTION : LOW INTENSITY PHASE

To a great extent, the potential conditions of environmental risks or stability in the mountains become a reality once the natural system is exposed to human-induced perturbations. Though often seen as a difficult place for human habitation, and characterised by low population densities compared to the plains, the mountains have historically been centres of flourishing civilisations and have sheltered religious and political refugees during different times in history. Associated with the above, has been the unavoidable human interference with the natural ecosystems (Eckholm 1975 and Hewitt 1988). However, traditionally the communities that lived and multiplied in the mountains, acquired better understanding of the limitations and potentialities of mountain environments. Their survival and growth strategies exhibited greater sensitivity to ecological and economic interdependencies. They adapted to mountain conditions well enough to minimise environmental risks (Guillet 1983 and Brush 1988). The resource management systems and practices they evolved generally proved conducive to the operation of biophysical processes and flows that helped ensure environmental stability. These worked quite well under the situation of low demand on mountain resources. These resource management and production practices can be seen in terms of traditional measures often grouped under folk agronomy, ethno- ecology, ethno-engineering, collective sharing systems, and recycling practices. Instead of describing them individually, we may refer to their key implications vis a vis the environmental stability through generation of circumstances potentially influencing the operation of biophysical processes and flows. Annex Table 2 lists some of the traditional practices in response to specific mountain conditions.

Most of the traditional practices were low resource intensive, and were governed mainly by local needs and local capacities to extract the resources. Table 2 summarises some of the adaptation measures and their role in helping circumstances conducive to environmental stability. Accordingly, despite human habitation, inaccessibility imposed constraints such as isolation and closedness, necessitated diversification, local resource regeneration, balanced resource use, etc. Similarly, local demand and local capacities to extract resources being low, the pressure on resources remained low. Through local control of the local circumstances, pressure on resources was deliberately kept low through various measures of demand-rationing, including social - cultural sanctions, periodical outmigration, etc (Guillet 1983 and Hewitt 1988). These measures contributed in different ways to generate circumstances conducive to the operation of biophysical processes and flows which helped to maintain environmental stability.

Fragility and marginality, the two features of mountain habitats that made mountain environments most vulnerable to degradation and prone to slow regeneration, were handled by a two way adaptation process under the traditional systems. Firstly, through land extensive production practices and uses (e.g., pasture and forestry, instead of intensive annual cropping) and institutional regulations (e.g., through provision of common property resources), usage systems were adapted to the limitations of the resources. By implication, these measures helped in better regeneration, flexibility, and improved energy and material flows. On the other hand, through ethno-engineering measures such as terracing, water harvesting, community irrigation systems, etc, the fragile and marginal resources were upgraded, and this helped in environmental stability through increased resilience, regeneration, and improved natural flows.

Diversification, through spatially and temporally diverse but interlinked activities, has been one of the most important features of traditional resource use systems. At a macro-level, this is reflected through balanced land use involving provision of forest, pasture, cultivable land, etc and at a micro-level, this is reflected through diversified cropping systems and other features of traditional farming systems. This sort of diversification, besides matching the imperatives of resource characteristics, also met the diversified needs of mountain communities in the relatively closed or isolated context of their habitats. More importantly, in a variety of ways, this helped in the processes contributing to regeneration, flexibility, and regulation of natural flows.

An important component of the overall diversification of activities to respond to resource characteristics was the focus of traditional systems on harnessing and protecting 'niche' or areas and activities of comparative advantage for mountains. Since 'niche' served as an important basis for upland-lowland linkages and a means of surplus generation and exchange, its protection and development was part of the survival and growth strategies of mountain communities. Thus, because of the crucial importance attached to protecting 'niche' and the key role of local needs and local extraction capacities in determining the usage level of mountain 'niche' (be it potential for hydropower, minerals, or timber), the resources were generally not over-exploited. Hence the harnessing of 'niche' did not disturb the dynamic processes and flows of nature.

All the above features of traditional resource use systems or farming systems are part of the human adaptation mechanisms in the mountain areas and have been evolved and inherited by mountain people through the centuries. These adaptations involved various other practices, such as product recycling, flexible consumption patterns, transhumance, and migration, which directly or indirectly facilitated regulation of pressure on resources and by implication proved conducive to the operation of biophysical processes for environmental stability. However, as indicated earlier, most of the traditional adaptation measures as responses to imperatives of mountain specificities were evolved in the context of low demand pressures on mountain resources. Low pressure, in turn, was the product of a smaller population and subsistence-oriented, local resource-centred agriculture as the dominant activity of mountain areas. Trade

Table 2: Mountain Specificities, Human Adaptations and Implications for Environmental Stability/Risk

Mountain specificities and features of adaptations[a]	Implications (circumstances) potentially conducive to environmental stability			
	Regene-ration	Variabi-lity	Resili-ence	Energy/ material flows
Inaccessibility (Isolation, closedness):				
Local (diverse) resource-centred production systems		X		
Local demand-driven, local capacity-based (low) resource extraction	X	X		X
Limited external reliance/support, compelling rationing of demand and resource use; social sanctions	X	X	X	
Fragility and Marginality (Limited and 'inferior' options, high vulnerability to disturbance):				
Land extensive production systems (annual perennial linkages); sanctions against overuse (common property resources), etc.	X	X		
Resource upgrading (terracing, irrigation), collective sharing systems	X		X	X
Diversity (Potential for multiple interlinked activities):				
Diversified farming system, spatial-temporal linkages of land-based activities, food systems and other demands tuned to diverse supplies	X	X	X	X
'Niche' (options/possibilities with comparative advantage):				
Local need - and capacity-based low and regulated extraction	X			X
Diversified and interlinked activities	X	X		

and industry (cottage industry) were largely linked to local resources ('niche') and agriculture. Furthermore, owing to limited external linkages, outside demand or market signals could not exert undue pressure on local resources. Besides low demands, non-availability of means (technologies and infrastructure) for large-scale extraction of mountain resources also prevented undue disturbance to the mountain environment through human interventions. However, the land extensive, non-extractive features of the traditional systems are not compatible with the resource use intensification forced by rising demands on mountain resources as elaborated below (Jodha 1991).

IV. ENVIRONMENTAL RISKS: RESOURCE INTENSIFICATION PHASE

The mountain environment - including the resource base, its production potential, and the biophysical processes and flows regulating the stability of the environment - is exposed to serious degradation following the intensification of resource use in the mountains. This degradation process manifests the cumulative type of global environmental change visible in several parts of the developing countries (Turner et al. 1990). Its more popularly understood or projected components are deforestation, overgrazing, extension of cropping to submarginal areas (i.e., steep and fragile slopes), landslides and mudslides, periodic flash floods, soil erosion, disappearance of vital biophysical resources, reduced resource productivity, etc. Some of these have been documented as emerging indicators of unsustainability (Jodha 1990a, 1990b).

We discuss these changes in terms of biophysical processes and flows and relate them to interaction between driving forces behind resource intensification and imperatives of mountain specificities. The forces or factors behind resource use intensification are rapid population growth, market-induced demand, and resource extractive public policies. The mechanisms (or immediate causes) include the creation of infrastructural facilities particularly to reduce the degree of inaccessibility, to support extraction of mountain 'niche' and to introduce new technologies, macro-economic policies, etc, designed to develop mountain areas and closely integrate them into mainstream economies, reduce regional imbalances, and eradicate poverty. However, whatever their explicit or implicit goals or the nature of mechanisms to implement them, most of the public policies in mountain areas are insensitive to the imperatives of mountain specificities.

Table 3 summarises some of these issues and their implications in terms of circumstances associated with environmental stability or risk in mountain regions. Accordingly, irrespective of the factors behind resource-use intensification, the invariable consequence is disruption of circumstances conducive to biophysical processes and flows (indicated by initial capital letters under Table 3), central to the stability and sustainability of mountain environments. Detailed discussion of these factors will follow shortly. At this stage it would suffice to indicate the consequences of the aforesaid factors vis a vis implications of mountain specificities resulting in over-extraction of resources, reduced diversification, etc and their final impacts in terms of distortions of biophysical processes and flows indicated by Table 3.

The literature on changing resource use patterns, productivity, and environmental deterioration and their possible causes in the Hindu Kush-Himalayas and other mountain systems in the developing countries would bear with the situation indicated above (Ives and Messerli 1989, Eckholm 1975, Rieger 1981, and Price 1981). Most of these changes can be analysed and interpreted both as manifestations of circumstances leading to disruption of bio-physical processes and, in some cases, consequences of such disruptions. Table 4 illustrates these changes.

Table 3: Interaction between Resource Intensification Factors and Mountain Specificities Affecting Environmental Stability/Risk in the Mountains[a)]

Factors causing resource use intensification (Human interventions)	Mountain specificities and implications				
	Inaccessibility (closedness, limited external linkages)	Fragility & Marginality (Incompatibility with intensive use)	Diversity (High potential for diversification)	'Niche' (Products, activities with comparative advantage)	Adaptations (Activities, practices tuned to mt. conditions)
Population growth, per capita increased activities, increased animal numbers	Excess pressure on local resources with limited outlet (R,F,N)	Resource use intensity beyond use capacity (R,F,S)	Pressure of food needs, reduced range of land-based activities (R, F, S, N)	Pressure of food needs, disregard or misuse of potential (R,S,F)	Disregard of resource extensive, diversified practices (R, F, N, S)
Market forces, trade links, pressure of external demand	Integration with mainstream market situation despite low physical accessibility (R,F)	Distant demand - induced over use, backlash of cash cropping (R, S)	Narrow specialisation, reduced diversification (R,F,S,N)	External demand induced over-exploitation, marginalisation (R,F)	Decline of environment sensitive local concerns, and practices (R,S,F)
Public Interventions: a) Infrastructure for accessibility, integration, harnessing of 'niche', etc.	Reduced isolation, increased integration and level of activities (R,N)	Direct and side effects on fragile/marginal resources, increased use level (R,S, N)	Increased use level, access-determined narrow specialisation (R, F, S)	Over-exploitation of high potential areas, products, disregard of side effects (R,N, F)	External contacts, loosening of traditional values, and measures (R, S,F,)
b) Technology with narrow focus on market signals, short-term needs, sectoral orientation, external origin/orientation	Application for improved mobility, integration (F,N)	Product maximisation, indifference to resource limitations, inappropriateness (R,F, S)	Narrow specialisation, focus on limited product attributes (R, F, S)	Commercial-extraction orientation, disregard of side effects (R, F, S)	Disregard of traditional wisdom, know-how (F, R, S,)
c) Macro-economic policies - price, tax, trade, investment, extraction, development strategies	Disproportionate focus on accessibility, integration, disregarding side effects (F, N, R)	Focus on current production, disregard of resource limitations, long-term consequences (R, F, S)	Narrow specialisation, through incentives support systems, disregarding organic linkages (R,F,N, S)	Focus on revenue generation, external demand, extraction disregarding the side effects (R, N, S)	Marginalisation of traditional systems, increased dependency, subsidisation (F,R)

a) Biophysical processes affected by intensive human interventions in the mountains are: R = Regeneration; F = Flexibility; Variability; S = Resilience; N = Nature's flows, (energy and material flows).

Table 4: Negative Changes as Indicators of Emerging Environmental Risks in Mountain Areas

Visibility of change	Changes Related to[a]		
	Resource Base	Production Flows	Resource Use/ Management Practices
Directly visible changes	Increased landslides and other forms of land degradation; abandoned terraces; per capita reduced availability and fragmentation of land; changed botanical composition of forest/pasture. Reduced water-flows for irrigation, domestic uses, and grinding mills.	Prolonged negative trend in yields of crop, livestock, etc; increased input need per unit of production; increased time and distance involved in food, fodder, fuel gathering; reduced capacity and period of grinding/saw mills operated on water flow; lower per capita availability of agrl. products; etc.	Reduced extent of: fallowing, crop rotation, intercropping, diversified resource management practices; extension of plough to sub-marginal lands; replacement of social sanctions for resource use by legal measures; unbalanced and high intensity of input use, subsidisation.
Changes concealed by responses to changes	Substitution of: cattle by sheep/goat; deep- rooted crops by shallow-rooted ones; shift to non-local inputs. Substitution of water flow by fossil fuel for grinding mills; manure by chem. fertilisers[b].	Increased seasonal migration; introduction of externally supported public distribution systems (food, inputs)[b], intensive cash cropping on limited areas[b].	Shifts in cropping pattern and composition of livestock; reduced diversity, increased specialisation in monocropping; promotion of policies/programmes with successful record outside, without evaluation[b]
Development initiatives, etc. - potentially negative changes[c]	New systems without linkages to other diversified activities and regenerative processes; generating excessive dependence on outside resource (fertiliser/pesticide based technologies, subsidies), ignoring traditional adaptation experiences (new irrigation structure); programmes focussed mainly on resource extraction	Agricultural measures directed to short- term quick results; primarily production (as against resource)-centred approaches to development; service-centred activities (e.g. tourism) with negative side effects	Indifference of programme and policies to mountain specificities; focus on short term gains; high centralisation; excessive, crucial dependence on external advice ignoring traditional wisdom; generating permanent dependence on subsidies.

Source: Table adapted from Jodha 1990a

a) Most of the changes are interrelated and they could fit into more than one block.

b) Since a number of changes could be for reasons other than environmental instability/risk, a fuller understanding of the underlying circumstances of a change will be necessary.

c) Changes under this category differ from the ones under the above two categories, in the sense that they are yet to take place, and their potential emergence could be understood by examining the involved resource use practices in relation to specific mountain characteristics.

The Emerging Risk Scenarios

Table 4 presents a broad picture of negative changes in mountain areas which could be interpreted as indicators of emerging environmental risk scenarios in the HKH Region. The table is based on macro-level data and observations as well as evidence from micro-level field studies in the selected hill areas of China, India, Nepal, and Pakistan (Banskota and Jodha 1990a). These changes may also be described as indicators of unsustainability of the present pattern of resource use in mountain areas.

The above negative changes may relate to: (a) resource base (e.g., land degradation), (b) production flows (e.g., persistent decline in crop yields), and (c) resource management/usage systems (e.g., increased infeasibility of annual-perennial intercropping or specific crop rotation) (Jodha 1990a). More importantly, for operational and analytical purposes, the indicators of emerging environmental risks and vulnerabilities can be grouped under the following three categories on the basis of their actual or potential visibility. (Table 4 illustrates them.)

Directly Visible Negative Changes

These can include the increased extent of landslides or mudslides, drying up of traditional irrigation channels (*kools*), increased idle periods of grinding mills or saw mills operated through natural water flows, prolonged fall in the yields of mountain crops, reduced diversity of mountain agriculture, abandonment of traditionally productive hill terraces, and increased extent of seasonal outmigration of the hill people.

Negative Changes Made Invisible

People's adjustments to negative changes often tend to hide the latter. Adoption of shallow-rooted crops as substitutes for deep-rooted crops resulting in erosion of top soil on mountain slopes, substitution of cattle by small ruminants due to permanent degradation or the reduced carrying capacity of grazing lands, introduction of a public food distribution system to alleviate increased inter-seasonal hunger gaps (local food production deficits), and small farmers leasing out their lands to concentrate on wage earning, illustrate this category of negative change.

Development Initiatives with Potentially Negative Consequences

A number of measures are adopted for meeting present or perceived future shortages of products at current or increased levels of demand. Some of the measures (changes), while enhancing productivity of, say, mountain agriculture in the short run, might jeopardize the ability of the system to meet the increasing demands in the long run. Chances of such happenings are positively linked with the interventions' insensitivity to specific mountain conditions and their imperatives for environmental stability.

To illustrate the above, any farm technology that increases mountain agriculture's crucial dependence on external inputs (e.g., fertiliser) and disrupts local regenerative practices, may eventually accentuate environmental risks. Similarly, any measure that disregards the fragility of mountain slopes and ignores linkages between diverse activities at different elevations in the same valley (e.g., farming-forestry linkages) and promotes monocropping may not prove sustainable. Likewise, any resource-extraction activity (e.g., hydropower projects) or service-centred activities (e.g., tourism) or welfare-oriented schemes (e.g., subsidies generating the permanent external dependency of mountain people) that ignore the side effects and long-term consequences may enhance the prospects of environmental risks for mountainous areas and people.

Table 4 summarises some visible or less visible negative trends relating to resource base, productivity, and management of mountain resources, largely in the context of agriculture: the dominant activity of the mountain people in the HKH Region. Evidence of resource degradation, productivity decline, and disruption of traditional resource management systems from other fields such as mining and industry (Bandyopadhyay 1989), infrastructural development (Paranjipye 1988), and tourism (Singh 1989) could be presented in the same manner. It may be reiterated that in some cases the changes listed in Table 4 are causes while in others they are consequences of disruptions of the biophysical processes and flows. Furthermore, in the ultimate analysis, circumstances underlying the above changes that act as causes of disruptions of biophysical processes and flows are associated with the resource use intensification in the mountains as discussed below.

V. RESOURCE INTENSIFICATION PROCESS : INCREASED HUMAN INTERVENTIONS

The causative factors or driving forces behind the process of resource intensification and consequent environmental risks in mountains are similar to the ones observed in other ecosystems (Blaikie and Brookfield 1987). Broadly speaking, they include human (and animal) population growth, trade and market-induced demand pressures and public interventions with general insensitivity to the imperatives of mountain specificities. The implications of these factors vis a vis mountain specificities and biophysical processes and flows have already been alluded to while commenting upon Table 3. In the following pages we simply describe the magnitude and role of these factors in resource intensification - induced environmental degradation.

Pressure on Mountain Resources

The very first reason behind environmental degradation in mountains is the sheer scale of demand on mountain resources vis a vis their carrying capacities and abilities to regenerate. The forces behind the mounting demand include the factors discussed below.

The Population Factor

One of the key factors to consider in the context of the scale of demand on mountain resources is the human population. Demand has increased rapidly because of the unprecedented growth in mountain populations, generating a threat to all efforts to bring about sustainable development of mountain areas. If the current growth rates continue, most mountain areas in the Hindu Kush-Himalayas will easily have doubled their population in another 15 to 20 years. This will further increase the pressure on natural resources and their use beyond their use capacities; reflected through extension of cropping to steep slopes and discontinuation of land extensive practices (Sharma and Banskota 1990). During the recent decades, population growth in some areas of the HKH Region has been unbearably high. Despite problems created by inaccessibility, marginality, and the inadequacy of facilities in the mountains, the 'health revolution' has contributed to this growth. On the other hand, traditional pressure management mechanisms, such as migration and the upgrading of resources, through terracing, irrigation, and crop technologies, have failed to keep pace with the growth in population. This has both current and future economic/environmental consequences. Against a background of stagnant production systems, inadequate infrastructural development, and the absence of alternative employment opportunities, people's sustenance strategies, in the context of mountain characteristics, place a high premium on the over-supply of labour, and this makes population increases inevitable in the mountains (Sharma and Banskota 1990). The qualitative changes in the population characteristics (i.e., reflected by increased individualism, factionalism, and commercial attitudes caused by market forces and survival pressures) also have had negative side-effects in terms of eroding the traditional institutional mechanisms (e.g., provision of common property resources and collective environmental security) in mountain areas (Jodha et al. 1990).

Livestock

The increase in livestock numbers has also contributed to the increasing demands on natural resources. In most mountain areas, the livestock population is equal to, if not greater than, the human population. The increase in livestock has been an important response mechanism of mountain farmers to deteriorating economic and environmental conditions, but it is clear that current growth rates are unsustainable in the context of widespread deforestation and overgrazing in the HKH Region (Sharma and Banskota 1990 and Jodha 1990a).

Market Forces

The pressure on resources through rapid human and animal population growth is further accentuated by market-induced demands. Governed initially by local revenue requirements and the desire to harness mountain 'niche', resource extraction ultimately becomes a function of distant demands and market signals. The latter, being insensitive to local circumstances and indifferent to its side-effects, accelerates the process of over-extraction. Evidence about deforestation for commercial use, mining activities, and the environmental insensitivity of hydropower and irrigation schemes from various areas in the HKH

Region corroborate this (Banskota and Jodha 1990a and 1990b, and Banskota 1989). At the micro-level, increased focus on cash cropping, especially horticulture and vegetable cropping in selected areas, has pushed staple food crops to more marginal, fragile slopes. Moreover, the 'servicing' of horticultural development (e.g., through wooden boxes for fruits and support sticks for several vegetables) has a high environmental cost in terms of deforestation (Banskota and Jodha 1990a).

An important dimension of market-induced resource extraction relates to the terms of exchange between mountain regions and the plains/urban areas that use the mountain products. The factor and product prices (to be elaborated later) are too low and they hardly reflect their real worth. This induces over-extraction of resources with no concern for long-term sustainability and side-effects.

The rapid resource use intensification in the face of massive growth in demand emerges as the immediate cause of several indicators of emerging environmental risks (Table 4). The possible solutions lie in restraining and regulating the pressure of demand (or rather its underlying driving forces such as population growth) or in ensuring higher use intensity of resources without its degradation. The latter calls for high productivity technologies with potential for rapid resource regeneration and conservation, suited to mountain conditions. This, in turn, would necessitate imparting the mountain perspective into R and D policies (Rhoades 1990 and Jodha 1991).

Macro-economic Policies

Macro-economic policies are not only instrumental in influencing the pace and pattern of development but also in conditioning the nature of activities that influence environmental stability and sustainability of mountain resources (Banskota et al. 1990). In the HKH Region, most of the negative trends, in several areas (Table 4), can be partly attributed to macro-level economic policies. The missing mountain perspective (i.e., lack of sufficient consideration of mountain specificities) is an important gap in these policies as most macro-level policies are not designed for the mountain context but according to conventional practices or experiences in non-mountain areas (Jodha 1990b and Banskota and Jodha 1990a and 1990b). This is so whether one looks at investment priorities and resource allocation, factor/product pricing and other fiscal measures, infrastructural development and agricultural R and D, or choice of scale and technologies for various activities (Banskota et al. 1990, Jodha 1990b, and Sanwal 1989). Some dimensions of macro-level policies that seem to have adversely affected the environment and hindered sustainable development in the mountains, evidence for which is available from different locations within the HKH Region, are briefly presented here.

Resource Extraction Policies

Notwithstanding the recent focus on the welfare of mountain people and on the need to reduce inter-regional inequities, historically speaking, the focus of macro-economic policies in the mountain areas has been directed towards the extraction of mountain resources, largely for use in the non-mountain hinterland (plains) or in urban areas within the mountain regions. The additional short-term consideration has been revenue maximisation. A third dimension of the State's approach to mountain areas in the HKH Region has its origin in the geopolitics of the region. Depending upon the concerned country's security perceptions, the patterns and goals of intervention (e.g., development or deliberate stagnation, integration, or isolation) are decided. However, whichever of the three perspectives one looks at, the regeneration and sustainable use of resources and environmental stability have seldom been the major considerations in State policies (Banskota and Jodha 1990b and Sanwal 1989). Both the mechanisms and procedures for resource extraction (e.g., classification of forests, system of contractors, auction arrangements for harvesting of timber, development of irrigation and power potential without referring to the interests of local communities) are decided within this context. Similarly, product pricing and compensation mechanisms are guided by conventional yardsticks, rather than on the basis of the intrinsic worth of products and the sustainability implications of the pace and pattern of resource extraction. The phenomenal growth in the demand for mountain resources, induced by distant market signals and with complete disregard for the 'resource use intensification question' in fragile mountain ecosystems, can be attributed to the above policies (Banskota and Jodha 1990b, Banskota et al. 1990, Paranjpye 1988, and Bandhyopadhyay 1989).

Public Sector Investment: Allocative Biases

In keeping with the 'resource extraction' focus of development policies, the investment or resource allocation patterns in mountain areas acquire certain specific features. Accordingly, most of the public sector investment is on infrastructural development (e.g., roads) or on projects designed to harness mountain potentials (e.g., irrigation and hydropower). Unfortunately, in most cases, their gains in terms of helping mountain agriculture and other local activities as well as people's survival strategies are limited (MFS 1990a, 1990b, 1990c, 1990d and Banskota and Jodha 1990a and 1990b). Because of their scale and investment requirements, they leave little resources for ancillary activities that facilitate fuller use of the infrastructure and harnessing of diverse resource potential. Diversification and interlinkages of activities - the very preconditions (determined by mountain characteristics) for relevance and effectiveness of an intervention in these areas, are usually overlooked in investment allocations. Environmental auditing of investment decisions is, of course, a far cry.

Besides the structure of investment, low level of resource allocation to mountain areas also contributes to stagnation of mountain economies and consequent degradation of natural resources because poverty and environmental degradation are closely linked. The constraints imposed by inaccessibility, fragility, diversity, etc raise the overhead and operational costs of development and service activities in the mountains, both on per unit and per capita basis. These very factors that cry for larger-scale of investment in the mountains are used for discounting investment opportunities in the mountains by the conventional norms used in feasibility studies (Banskota and Jodha 1990b and Jodha 1990b). The consequence is persistent under-investment in mountain areas, leading to stagnation, poverty, and environmental degradation.

A related aspect of public sector investment is what may be called the '**development culture**' associated with public interventions in the mountains. Accordingly, the important features of public policies for mountain areas are centralisation in decision-making, perpetual subsidisation of development activities, and substitution of traditional self-help and resource protection devices by formal State interventions. Although initiated as a part of the extension of generalised public interventions in rural areas (in the mountains and elsewhere), they have had several negative side effects including people's alienation from resources, resource degradation, increasing costs and subsidisation of development activities, and a variety of inequities (Sanwal 1989 and Jodha et al. 1990).

Technologies

While science and technology have helped in resource-use intensification without undue environmental risks in different areas of the world, in the mountain areas, especially in the HKH Region, this has not been seriously tried. On the contrary, science and technology have been applied with little concern for their side effects. Examples such as the creation of massive power transmission lines and network of roads ignoring fragile rock alignments (Deoja and Thapa 1991), extraction of minerals (Bandyopadhyay 1989), generation of power through huge equipment and infrastructurral facilities little sensitivity to their side effects (Paranjpye 1988), and introduction of new cropping systems emphasising mono-culture and narrow specialisation (Jodha 1991) abound, where modern science and technology have been applied indiscriminately. Often the primary goal here, as in other public interventions, is resource extraction and short-term gains. However, more than the goals, the very approach to development and use of scientific technologies for mountain areas needs to be questioned.

In most cases, technology, despite its irrelevance, is directly transferred to the mountains from the plains. In none of the countries of the HKH Region does the existing R and D infrastructure match with the requirements or proportionate importance of the mountain areas and their contribution to national economies. Even if some technology development work is carried out in the mountains, the objectives and approach are seldom in keeping with the imperatives of mountain specificities. Agricultural R and D offers the best example in this respect, where work on new technologies (e.g., choice of cultivars, their attributes, types of cropping system) completely disregard the imperatives of mountain specificities such as diversity, fragility, and inaccessibility (Jodha 1991).

The above features of public interventions that reveal their insensitivity to mountain specificities, are corroborated by reviews of selected public policies and programmes in Himachal Pradesh in India (MFS 1990a), West Sichuan and Xizang in China (MFS 1990b), Nepal (MFS 1990c), and the NWFP in Pakistan (MFS 1990d). The site-specific case studies of farming systems in the same areas, which also covered the processes and impacts of development interventions, revealed several changes (Table 4) that are less conducive to resource conservation and environmental stability (Jodha et al. 1990). Reversal of these policies can be initiated through conscious incorporation of the mountain perspective into public interventions. To support this reasoning the experience from the study areas indicated above may be cited. The experiences of a few "success stories" from the HKH Region indicated some prospects of economic betterment without degrading the resource base and environment. These cases included the integration of traditional and modern technologies for mountain agriculture, institutional innovations conducive to participatory development with greater focus on stability and productivity of environmental resources, local, renewable resource-centred cottage industries, and local 'niche' - centred integrated area development initiatives. The common factor in nearly half a dozen successful cases of rural transformation covered by the above reviews was their (conscious or unconscious) incorporation of the mountain perspective into their programmes (Jodha et al. 1990).

To sum up, the role of public policies in enhancing environmental risk in the mountains can be stated as follows. Public policies and programmes are directed to (i) integration of mountain areas with the plains and urban areas through market and infrastructure, (ii) extraction of mountain potential through technology and lop-sided investment strategies, and (iii) substitution of (a) traditional diversified resource use systems by commercially and sectorally oriented, standardised arrangements and (b) traditional self-help by subsidisation, creating permanent dependency of mountain areas and people on external help. All of these contain seeds of environmental instability in one form or another.

VI. 'CUMULATIVE' - 'SYSTEMIC' CHANGE LINKAGES

The preceding discussion has described various facets of the cumulative type of environmental change in the Hindu Kush-Himalayan mountain region. This has also highlighted the central role of interactions between attributes of mountain resources and features of resource use systems in enhancing environmental risks. The process of resource use intensification, guided by several driving forces, has been described. With the unabated role of these forces, mountain areas and communities are in for greater environmental instability and its consequences. The level of instability and risks is already quite serious, even without the impacts of global systemic changes (e.g., global warming). The latter can further accentuate the situation.

The Impact of Systemic Changes

Details on potential systemic changes affecting the mountain areas under review are almost negligible when compared to the information on cumulative changes discussed above. However, with full recognition of the limitation of the information on systemic changes (e.g., their conjectural nature and associated uncertainties of predicted change scenarios), a few possibilities may be stated. Accordingly, the potential changes in the HKH Region resulting from global warming, as summarised for an ESCAP meeting (Topping et al. 1990), includes the following points.

(i) Because of warming, forests (the unmanaged ecosystems) may undergo both quantitative and qualitative changes. Some of the species may disappear and others may move spatially. This may accentuate the already known current negative trends relating to forest areas. The resulting reduced biodiversity may influence both biophysical functions and flows governing the environmental stability as discussed earlier. This may make the economy and survival strategies of people more vulnerable to risks.

(ii) The region may have higher rainfall (convective high intensity rains). This may cause increased runoff, flash floods, soil erosion, mud and land slides, and can influence overall farming systems. Impacts of such changes on the circumstances affecting basic biophysical functions and flows, on the one hand, and people's survival strategies, on the other, hardly need elaboration.

(iii) Increased warming will lead to increased snow melting and consequent disturbance to hydrological cycles, seasonality of waterflows, and related impacts on land use, cropping intensities, etc, disturbing the already threatened diversity and sustainability of mountain resource use. The environmental risks will be further accentuated.

(iv) To the above potential changes one may add a few more possibilities. The latter relates to likely changes in the specific mountain conditions (fragility, diversity, 'niche', etc.) and their interrelationships. This, in turn, may generate new constraints and opportunities, influencing the comparative advantages of mountains and their links with other regions and perspectives of public interventions in mountain areas. At the micro-level, the agricultural systems covering all land-based activities may undergo several changes including disturbance to well-adapted cultivars and management practices, product and income flows, as well as people's strategies to cope with risks (Jodha 1989) which, in turn, may influence the resource use pattern with implications for environmental stability.

To sum up, the combined impact of all the above changes may result in increased compulsions or incentives (opportunities) for resource use intensification, which, in turn, may accelerate the already observed cumulative changes and their impact on vital biophysical processes and flows.

Accentuation of "Cumulative" Change

A total view of the environmental risks in the mountains caused by global changes can be had by a combined perspective of 'systemic' and 'cumulative' changes. Accordingly, Table 5 presents some possibilities of current trends in resource degradation (cumulative changes) likely to be accentuated by the impacts of global warming (e.g., systemic changes). The impact of the combined role of the two types of changes on biophysical processes and nature's flows is indicated by the capital letters in Table 5.

Table 5: Potential Accentuation of 'Cumulative' Change-led Environmental Risks Due to Impacts of 'Systemic' Change

Current problem (cumulative type of change) likely to be accelerated by systemic change	Potential key manifestation of 'systemic' change (impacts of global warming)		
	Vegetation changes: forest size, location, composition, growth cycle; bio-diversity, interactive processes	Increased convective rains: floods, run off, soil erosion, changes in growing season, hydrological cycle	Warming-led snow melt: increased waterflows, soil erosion, changes in the hydrology of mountains and flood plains
Deforestation, vegetation degradation, reduced diversity	X (R,F,N,S)[b)]		X (R,N,F)
Soil erosion, land and mud sliding, floods		X (N,F,S)	X (N,F)
Changes in land use pattern, reduced diversity of farming systems, increased resource use intensity and degradation	X (R,F,N)	X (S,N)	
Increased vulnerability of people's survival strategies to environmental instability due to resource degradation and disruptions	X (R,F)	X (R,F,S)	X (R,S)

a) See Table 4 for details of some of the negative changes indicating emerging environmental risks.

b) The capital letters indicate biophysical processes and flows likely to be affected: R = Regeneration; F = Flexibility, Variability; N = Resilience; S = Energy and material flows (see text).

Accordingly, potential impacts of global warming-led changes in forests and vegetation may accentuate the current problems associated with deforestation, land use intensification, overgrazing, landslides, etc. The changes in waterflows caused by warming-led snow melt or increased convective rains will also accentuate the current problems stated above. Thus the current crises reflected through 'cumulative' changes in mountain areas, in a way, manifest the degree of vulnerability of mountain habitats and the people to potential negative impacts of systemic changes.

VII. SOCIOECONOMIC VULNERABILITIES

So far, we have focussed on environmental changes and risks largely in terms of disturbance to biophysical processes underlying the flow of environmental products and services used by human society. Disruption of the above flows through cumulative and, to a limited extent, systemic types of environmental changes was highlighted. Occasionally, we alluded to the impacts of these disruptions on the survival and growth strategies of mountain communities. However, these issues need more systematic treatment. Hence, a need to comment upon the socioeconomic and socio-cultural vulnerabilities of mountain communities to risks associated with environmental changes. However, for doing so we will focus on environmental resources and their impacts on socioeconomic variables (including opportunities and human decisions), rather than on the basic biophysical processes determining the flows and stock of environmental services.

The socioeconomic vulnerabilities, at the operational level, are reflected through reduced range, viability, flexibility, dependability, and pay-offs of production and resource use options to satisfy human needs. In the mountain context, on the technology side, this may happen due to break down or infeasibility of diversified, resource regenerative practices as well as degradation of natural resource base. On the institutional side (where institutional change may take place in order to adapt to the changing biophysical opportunities), slackening of resource management/protection systems, reduced resource accessibility, reduced range and quality of options, marginalisation of collective sharing systems, etc will manifest the extent of socioeconomic vulnerability.

While discussing the indicators of emerging environmental risks in mountain areas (Table 4), such changes were already commented upon. However, some of these changes are impacts of disruption in environmental and natural resource situations, while others could be causes of such disruptions because the socioeconomic adjustments to environmental change may cause further changes in the environmental situation at second or third level downwards.

The mechanism begins with increased scarcities due to internal demands or external pressures on water, vegetation, and soil resources (as indicated by capital letters in Table 6). It results in direct over-extraction or promotion of adjustment measures that are more resource extractive. Each of them contribute in different ways to increased socioeconomic vulnerabilities in terms of reduced range and

Table 6: Environmental Changes and Socioeconomic Impacts/Vulnerabilities in Mountain Areas[a)]

Environmental changes and underlying factors or responses to change	Socioeconomic impacts/vulnerabilities			
	Unfeasibility of traditional production systems, regeneration, resilience	Reduced range/quality of options, control, access to resources	Increased external dependency, unequal exchange, subsidy, marginalisation	Reduced collective sharing systems, low resilience, cultural breakdown
Physical degradation of land resources (W,S)[b)]	x	x		
Reduced variability, flexibility of production factors (V,W)	x	x	x[p]	
Increased 'ecological' subsidisation through chemical, physical, biological inputs (V,W)			x[p]	x[p]
Vicious circle of resource degradation overextraction-degradation (W,S)	x	x	x	
'Niche', technology, market induced over-extraction, reduced resource availability/access (V,W,S)		x	x[p]	x[p]

a) Details presented in the table largely relate to agriculture dominated by stagnant production systems; but the items indicated by (p) apply to progressive agricultural areas also.

b) The capital letters stand for worsening of the situation caused by internal scarcities and external pressures with regard to: W = Water, V = Vegetation, S = Soils-resources likely to be affected by environmental degradation.

quality of options, time-tested traditional resource management systems, etc. Table 6 gives an indication of these possibilities. These possibilities relate mainly to the predominant activity of mountain communities, i.e., agriculture. However, such formulation can be presented with respect to other activities such as tourism, trade, as well as macro-economic interventions.

Vulnerabilities to 'Systemic' Change

The argument on linkage between 'cumulative' and 'systemic' changes can be easily extended to socioeconomic vulnerabilities to environmental risks in mountain areas. The involved issues can be discussed in the following contexts.

First, to the extent that global warming-induced changes are likely to have more severe impacts on poor and marginal areas, i.e., areas with a higher degree of present crises (for whatever reasons), the mountain regions and communities with a current status of environmental degradation and associated socioeconomic disruptions may face a still worse situation with the potential changes associated with global warming. This will be due both to erosion of their capacities to withstand the future crises as well as aggravation of resource extraction, imbalances, and scarcities.

Second, impacts of the off-site factors, such as external demand-induced resource extraction and marginalisation of mountain areas and communities, are likely to be aggravated with systemic environmental changes. In particular, one may think of increased external pressure on water, space, and vegetation (including bio-diversity) resources of the mountains. The scale, and technologies to be employed in this process of resource extraction to meet the needs of off-site communities may further disrupt the survival and growth strategies of mountain communities.

Possible Response : Dual Purpose Strategies

If our understanding of linkages between cumulative and systemic changes is correct, the measures against the above stated socioeconomic vulnerabilities can begin with the strengthening of the mountain communities' ability to withstand the problems created by current resource degradation and environmental changes. This, in turn, calls for steps that enhance resource use intensification with resource regeneration and conservation. In other words, environmental stability and productivity in the current context has to be achieved to enable people to withstand impacts of systemic changes in the future. Accordingly, technological and institutional steps directed towards enhancing the health and productivity of environmental resources (land, water, vegetation) in the current context will also help in their long-term sustainability. By implication, such steps will control the cumulative type of changes and (due to their essential linkages) will also control systemic changes. This, in a way, is the essence of 'dual strategies' directed simultaneously to systemic and cumulative changes as well as 'regional' and 'global' environmental changes (Jodha 1990c). The scientific and institutional prescription against global warming and its impacts (IPCC 1990) will have greater chances of success if they are integrated into dual purpose strategies. This will reduce the role of uncertainty of modelled scenarios in obstructing evolution of workable and readily acceptable strategies against systemic changes.

This can be elaborated. One of the principal reasons for such inaction is the degree of uncertainty associated with modelled change scenarios which, in turn, causes other problems, such as the varying perceptions of different nations on potential impacts of environmental changes and sharing of cost and gain of strategies against it. In the broader context of uncertainty-induced inaction against environmental change and associated risks, an understanding of potential linkages between cumulative changes and systemic changes can offer certain useful leads (Jodha 1990c). As the severity of the impacts of cumulative changes is likely to be enhanced through systemic changes and vice versa, measures against any one of them would help reduce environmental risks. Since the cumulative changes are more certain and already witnessed as a reality, measures against them are less likely to be obstructed by the phenomenon of uncertainty . Similarly, as the spatial context of cumulative changes is more concrete (e.g., deforestation in the Himalayas), the response measures against them (unlike systemic changes) would not be constrained by lack of any regional disaggregation of the problem. Finally, since cumulative changes are a part of the current problems in the developing countries, any measures against them would neither need intensive lobbying and consensus building (as tried against global warming) nor any diversion of resources away from the current problems of poverty and underdevelopment.

Finally, if designed as dual purpose strategies, the gains from such measures (e.g., management of forest, land, and water resources) may strengthen people's capacities to withstand environmental risks associated with both cumulative and systemic changes (Jodha 1990c). Accordingly, a search for dual purpose strategies should be the focal point of approaches to environmental management in mountain areas.

The dual purpose strategies against environmental risks cannot be confined to the supply side-issues of the problem. In other words, no measures designed to regenerate, recycle, and diversify resources (for environmental stability) will help in the long run unless pressure on resources and associated extraction technologies are also managed.

The emerging indicators of cumulative and systemic changes in the ultimate analysis are consequences of mismanagement or free play of basic human driving forces, such as competitive and inegalitarian systems of resource exploitation, unequal terms of exchange, population growth, etc. In the face of these forces, no breakthroughs in resource regeneration or productivity, or growth will help in the long run. What has been stated above applies to the world economy, in general, but this is more so in fragile resource zones, such as the mountains, where the demand-induced resource extraction reaches its limits too soon. Hence, the solution to environmental risks in the mountains is closely linked to the management of internal and external pressures on mountain resources. In this context, a few important operational leads could be provided by better understanding of upland-lowland linkages and the side effects of the integration of mountain economies with the mainstream economies through market, infrastructure, and administrative processes (Jodha et al. 1990).

ANNEX

Table 1: Indicators of the "Skewed Perspectives" on Global Environmental Changes[a)]

Elements prominently focussed	Elements under emphasised
'Systemic' type of change: Focus on biochemical variables and their interaction processes relating to the functions and operation of geosphere and biosphere systems of the earth.	**'Cumulative' type of change:** Localised and widely replicated changes in different variables and process of resource use, (when accumulated) influence the global systems.
'Geocentric perspective': Focus on physical dimensions, typically in the natural science framework; concentration on geobiological variables and their complex interaction patterns, with little direct incorporation of human dimension of changes and change-processes.	**'Anthropocentric perspective':** Primacy of nature-society interactions with focus on their importance to the society; potential mechanism for understanding and handling 'cumulative changes' (with some possibility of influencing impacts of 'systemic changes'.
Other associated aspects: Emphasis on long time horizon (decades/centuries), inter-generational issues; focus on terminal impacts involving selected variables (e.g., sea level, and temperature rise, shift of climatic zones, etc) affecting fundamental equilibrium of world system and atmosphere; analytical methods and material used involve high degree of complexity and sophistication, information on several unknowns, limited transparency (for uninitiated ones), multiple uncertainties, and conjectural nature of predictions.	**Other associated aspects:** Sensitivity to both intra-generational and inter-generational issues; analytical approaches simpler and oriented to integration of change processes in current problem-solving mode; predictions, action/advocacy focus on short or medium planning horizon, greater ease and possibility of associating causes, consequences of and responses to change; greater possibility of integrating geocentric and anthropocentric perspectives.
Advocacy and action: High 'scarce and noise' potential of issues covered, (e.g., doomsday predictions); approaches to abate/adapt to changes: obstructed by uncertainty of change scenarios, induce higher discounting of the potential options, inject vagueness about gains and sacrifices and create more panic and debate than concrete action.	**Advocacy and action:** Possibility of evolving options within the received (and modified) framework of handling current crisis situations in local contexts; greater scope for clearly associating cost and benefits, greater certainty of potential options and their easy acceptability to decision-makers; possibility of dual purpose options to handle current and future 'impacts'.

a) Source: Table adapted from Jodha (1990c)

For various issues and examples which could fit into the following grouping of perspectives see Price (1990), Turner et al. (1990), Flavin (1989), Jodha (1989), Glantz et al. (1988), Clark (1985), Chen et al. (1983), and Kasperson et al. (1990).

Table 2: People's Traditional Adaptation Strategies in Response to Mountain Specificities

Adaptation Measure	Mountain Specificities[a]				
	I	F	M	D	N[a]
Diversification and Self-provisioning:					
o Spatially, temporally interlinked activities	x	x		x	x
o Local resource-focussed recycling, self-provisioning		x		x	x
o Scattered settlement patterns	x			x	
Folk Agronomy:					
o Annual - perennial plant complementarities (farming-forestry linkages etc)		x	x	x	
o Cultivars of varying attributes		x	x	x	
o Fallowing, rotations, topo-sequencing, intercropping	x	x	x		x
Ethno Engineering:					
o Slope management (terracing, etc.)		x	x		
o Protective vegetation, contour farming		x	x		
o Traditional irrigation/drainage management			x	x	x
o Small-scale transport logistics (ropeways, trails, donkey tracks, etc)	x				
Collective Arrangements:					
o Common property resources		x	x	x	
o Social regulations for use/protection of fragile resources		x			
o Community irrigation systems, etc		x	x	x	x
o Crisis period sharing systems	x	x	x		
Upland-lowland Linkages:					
o Petty trading in specialised mountain products (with high value, low weight etc).					
o Periodical migration	x			x	x
o Transhumance	x	x			
o Externally planned extraction of mountain 'niche'	x	x			x

Source: Table adapted from Jodha 1990a.

The following letters stand for the respective mountain characteristics: I = Inaccessibility, F = Fragility, M = Marginality, D = Diversity, N = 'Niche'.

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ICIMOD is the first international centre in the field of mountain development. Founded out of widespread recognition of environmental degradation of mountain habitats and the increasing poverty of mountain communities, ICIMOD is concerned with the search for more effective development responses to promote the sustained well being of mountain people.

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