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“Land Use Transition and Human Health in Eastern Himalayas: an Adaptive EcoHealth Approach”

Critical linkages between Land Use Transition and Human Health in the Himalayan Region

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Abstract

Human transformations of landscapes affect both the ability of the ecosystem services and human health. Human health is increasingly facing greater challenges from land use transition related to globalization and environmental change. This article reviews the critical linkage between land use transition and human health in the Himalayan region by applying the Ecosystem Approaches to Human Health (or EcoHealth). Land use transition in the Himalayan and similar regions includes sedentarization, agricultural intensification, habitat modification, migration, change of livelihoods and lifestyles, biodiversity loss, and increasing flash floods. These transitions are driven by state policies, a market economy, and climate change, all of which can have remarkable effects on human health. Good human health is dependent on access to ecosystem services for food, nutrition, medicine, fiber and shelter, fresh water, and clear air. Ecosystem management has been a key means of controlling disease vectors and creating suitable habitats for human well-being. It aims to identify the web of environmental factors that influence human health, and thus enable human communities to improve natural resource management for health and the health of the ecosystems. The institutional and policy issues for land use and health transitions are also discussed.

Key words: Himalayas, land use, EcoHealth, human health, ecosystem services, diseases, health risk

1. Introduction

Although the lifespan of human beings has significantly increased, health risks increase with greater exposure to environmental change, particularly through land use and land cover change, such as deforestation, rangeland modification, agricultural intensification and urbanization. Most emerging human diseases are driven by human activities that modify the ecosystems or otherwise spread pathogens into new ecological niches (Taylor et al., 2001). An ecosystem is a well-functioning self-regulated system through competitive and cooperative mechanisms among its various components (Cairns, 2004). Human activities through land use practices have generated both “positive” benefits (such as continuing increases in food and fiber production) and “negative” costs (species extinction, soil erosion, land degradation, water pollution and global warming). However the pace, magnitude and spatial reach of land cover and land use change have increased over the past three centuries, and more particularly over the last three decades as a result of human activities that may go beyond ecosystem recovery capacity (Lambin and Geist, 2006). Land use either directly or indirectly affects human health in many ways (Patz and Norris, 2004; Carlos et al., 2005; Chhabra et al., 2006). It directly affects fauna and flora (Sala et al., 2000), contributes to local, regional and global climate change (Chase et al., 1999; Houghton et al., 1999; Pielke, 2005); and is the primary source of soil, water and land degradation (Scherr and Yadav, 1996; Schreier and Shah, 1996; Sthiannopkao et al., 2007). Altering ecosystem services—i.e., the benefits people obtain from ecosystems such as provisioning services (e.g., food, water), regulating services (e.g., predator/prey relationships, flood and disease control), cultural services (e.g., spiritual and recreational benefits), and supporting services (e.g., pollination, nutrient cycling)—that maintain the conditions for life on Earth (Millennium Assessment 2005), affects the ability of biological systems to support human needs (Vitousek et al., 1997; Cassman et al., 2005). In addition, human health risks are increased by adding to the toxicological risks resulting from bioaccumulation of toxic substances from global and regional environmental degradation (Rapport et al., 1998; Darnerud, 2003), and disease outbreaks resulting from disruption of species dynamics in controlling disease emergence (Berrang Ford, 2006). Such changes also in part determine the vulnerability of coupled human–environment systems to climatic, economic or sociopolitical perturbations (Turner et al., 2003; Kasperson et al., 1999; Ezzati et al., 2002). Therefore, land use decisions are also human health decisions.

The paths and rates of land use change are often driven by the local political economy, but are mostly determined by the market economy and political control (Xu, 2006), crosscut by current modes of globalization (Lambin and Geist, 2001). Therefore, land use transition is also socioeconomic transformation. Land use transition theory derives from the notion of 'environmental Kuznets curves', which predict nonlinear transitions in resource use as incomes rise over time (Rudel et al., 2005). Understanding land use transitions is crucial because the most profound impacts on human health occur during periods of transition between different land use states (Mustard et al., 2004). Impacts are scale-dependent in that some affect the local environment (e.g., water quality), while others extend far beyond the location from where they arise (e.g., carbon cycle, climate change) (Subramanian, 2004; Mustard et al., 2004). Not all land use changes are irreversible; ecosystems have their own capacity to absorb disturbances. Additionally, humans, as part of the ecosystem, can shape and reshape the capacity of ecosystems to generate services. Human and natural social–ecological systems are complex, self-organizing, and resilient, dominated by nonlinear phenomena (Berkes and Folke, 1998). However, multiple effects may overlap and reinforce each other (such as nutrition, poverty and human health). Social, political and economic pressures are responsible for substantial local and global transformations of land (Houghton et al., 1999; Ramankutty and Foley, 1999; Tilman et al., 2001; Geist and Lambin, 2002). Despite improvements in understanding land use change science, the potential impacts of land cover and land use changes on human health are poorly enumerated and understood.

Human health is highly dependent on access to ecosystem services for food, nutrition, medicine, fiber and shelter, fresh water and air, and amenity and recreation through different land use practices. The health of people and of ecosystems is negatively affected by decreased and inferior agricultural production caused by transformations in physical and human environments. For example, the excessive use of chemical pesticides and fertilizers, salinization, contamination by heavy metals, and soil depletion has degraded more than 10 million hectares of land, which directly affects human health (Lebel, 2003). Many infectious diseases (such as malaria, Japanese encephalitis and schistosomiasis), diseases arising from poisoning/contamination from fluoride (Gikunju et al., 2002) and arsenic poisoning (Anawar et al., 2002; Duker et al., 2005) have known links to the anthropogenic ecosystem, or human land use activities. Infectious diseases are a product of the pathogen, vector, host and environment. Noncommunicable diseases are also linked to environmental factors such as imbalanced minerals, diet and nutrition, lifestyle, and environmental pollutants. The pattern and extent of change in incidences of a particular infectious disease, among others, depends on the particular ecosystems affected, type of land use, disease-specific transmission dynamics, sociocultural change, and susceptibility of the human population. Health risks from increasing mountain hazards (earthquakes and flash floods) and socioeconomic transformation, as well as development displacement such as dam construction (WCD, 2000) need more attention. These events expose populations to a totally alien environment and health risk without adequate prior knowledge.

Ecosystem management has been, for millennia, a key means for controlling disease vectors and creating suitable habitats for human health. The status of human health is a reflection of a whole variety of complex interactions between the internal biological and the total external environmental systems. At this point in history, however, the scale of environmental change, accelerated by global warming and globalization, leads to new, emerging, reemerging, and redistributing diseases. Trends ranging from forest clearance to climate-induced habitat changes also appear to have impacted on certain populations of mosquitoes to alter transmission patterns for diseases such as malaria. Environmental factors are responsible for over 21% of the global burden of disease (WHO, 2004). Health effects of one particular land use change should be assessed within the context of other coexisting environmental effects and occurrences, such as rapid urbanization, migration and increasing mobility, increasing movement of production, resource exhaustion, desertification, and pollution. However, certain population groups, either because of their lifestyles or livelihoods, are vulnerable to specific health risks and threats. This, in combination with a differential hazard exposure, may put particular groups, such as women and children, at increased health risk (Gopalan and Saksena, 1999; Dreyfuss et al., 2000; Ezzati et al., 2002; Pinheiro et al., 2007). The vulnerable groups, including indigenous herders, farmers, and shifting cultivators, have the double burden of not only battling traditional hazards such as floods, drought, and water sanitation, but also face increasing exposure to HIV/AIDS, atmospheric brown clouds (ABC), industry pollution, and new influenza strains such as avian flu, in transition to a market economy and increasing population dynamics.

Although the ecosystem and human health issues have been a focus for research and development for decades, the linkage between ecosystem services and human health is inadequately addressed. The Ecosystem Approaches to Human Health Program (or EcoHealth) launched by Canada's International Development Research Centre (IDRC) is an innovative response to human health problems resulting from the local and global transformation of ecosystem, environment and human health (Waltner-Toews, 1996; Forget and Lebel, 2001; Lebel, 2003). The ecosystem and health relationship can be measured by potential indicators in environmental health-risk exposure, human morbidity or mortality, or human well-being and ecosystem sustainability approaches (Cole et al., 1998; Rapport, 2002; Rapport and Singh, 2006). Much work has been accomplished on environmental health risk assessment such as mining (Gabaldon, 1983), land use change such as deforestation (Wilson et al., 2002), monoculture and agricultural intensification (Oaks et al., 1991), atmospheric brown clouds (Ramanathan and Ramana, 2005), contamination from endemic fluoride, and mercury (Zhang and Wong, 2007), arsenic contamination (Maharjan et al., 2005), and thallium contamination (Xiao et al., 2004). However, the critical linkage between land use changes and human health risks in the mountain ecosystem has not been well understood by scientists or decision makers.

A responsive strategy for managing land use transition and human health risk is an emerging imperative for transdisciplinary scientists and policy makers. This article is an attempt to review the current threats posed by land use transitions to human health and to further understand the links between them in mountain habitats of the Himalayan region.

2. EcoHealth approach in the Himalayan region

2.1. Review framework

Multiple factors contribute to human health. One such factor is human disturbance of ecosystems and their services through land use changes that affect health risks by means of biological mechanisms and ecological processes (Fig. 1). Human activities not closely associated with environmental modifications also have a role in the production of diseases. Ecosystem management through land use practices can mediate the influence of anthropogenic activities in changing the epidemiological patterns of human diseases by reducing or increasing disease incidence. Most ecological systems have a unique set of infectious diseases; however, some diseases, such as malaria, are ubiquitous and can be found across ecological systems such as drylands, forests, and wetlands, although with somewhat different dynamics (MA, Chapter 14: Human Health).

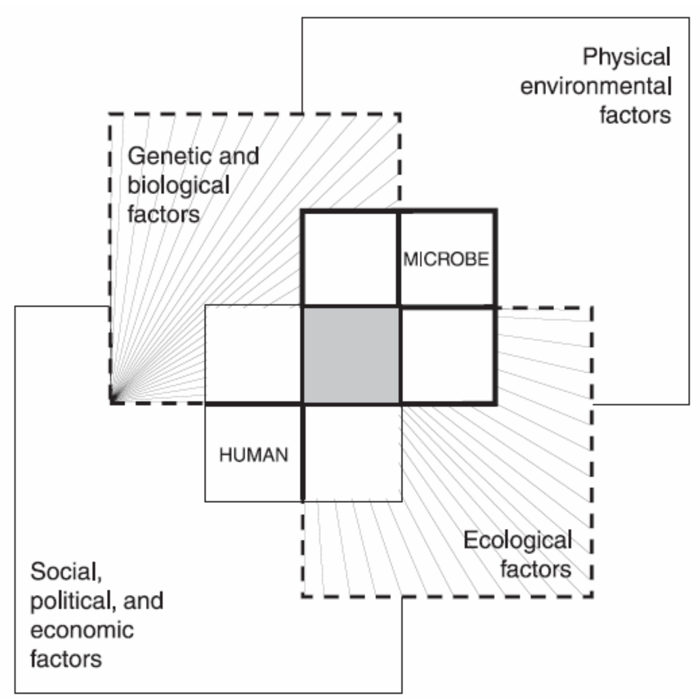

Fig. 1. Multiple Causes of Human Health (Institute of Medicine, 2003, adopted from Millennium Ecosystem Assessment)

With the processes of globalization and environmental change, land use transition is inevitable in the Himalayan landscape. Land use transition is illustrated by land use and habitat change, which ultimately changes ecosystem services. The relationship between land use transition, ecosystem services, and human health is shown in Fig. 2. Land use and habitat changes or disturbance of a particular ecosystem can have biophysical and socioeconomic effects that increase or decrease health risks and diseases. Some societies might be more vulnerable than others due to their different exposure to health risks and access to health services.

This review deals with the current state of knowledge on the interlinkages of land use transition and, consequently, the impacts upon human health in the mountainous regions by looking into: (a) the environmental health risk; (b) sedentarization in alpine rangeland and tropical forest ecosystems; (c) intensification of land cultivation; (d) habitat modification and development displacement; (e) migration, land use and HIV/AIDS; (f) biocultural diversity and nutrition; (g) mountain hazards and floods; and finally; (h) climate change. A key review question is how positive or negative impacts of land use and habitat changes are distributed among stakeholders including different gender groups. Wherever possible, we include the social, economic and political concerns of land users and various other groups of stakeholders involved. Also, inherent to our summarization is an assessment of the resilience of the ecosystem because multiple changes and impacts also determine, in part at least, the vulnerability of the coupled human–environment systems, and particularly human health.

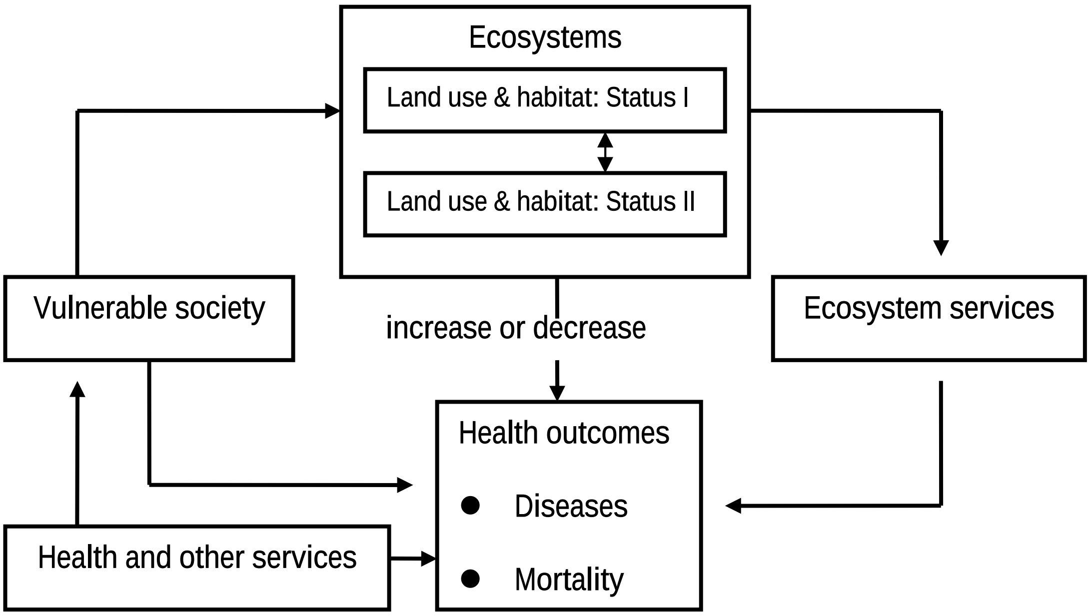

Fig. 2. Causal linkages between land use transition, ecosystem services and human health

Human health is arguably the most complex of the major types of global change impacts on societies. Understanding how to prepare for these impacts and enhancing the resilience of human–environment systems is surely one of the grand challenges ahead. In addition to ecosystem services are those influences that govern the distribution of disease-transmitting insects, and of irritants and pathogens in water and air. Accumulating evidence, however, suggests that local human–land interactions can now be held responsible for some consequences to human health. For example, the reemergence of malaria is associated with an intensification of land use. There are also direct effects of land use changes on the habitat of vector-born diseases such as malaria, African trypanosomiasis and dengue fever. There are also several indirect effects of global warming upon human health (Sutherst, 2001).

2.2. The Himalayan mountain perspective

The Himalayan region is the source of eight large river systems that provide water and other ecosystem services for almost one-third of the world's population. During the past decades, the framework conditions in the region have substantially deteriorated. Environmental change has become more visible: the retreat of glaciers, increasing irregularity of precipitation, growing carbon dioxide output as a consequence of the economic growth on the plains, as well as the increased frequency of natural disasters, are indicators of these changes. Globalization and economic liberalization have been major factors in converting the economies of India, Pakistan and China into growth poles of the world economy. Asia's growing economy needs more land, including steep-sloped mountain areas for plantations. The competition for more intensive use of water and land has become part of growing imbalances and often leads to higher migration, to poor health and poverty, and to precarious land use patterns. The mountain areas have not received the attention required in order to counterbalance the negative trends. High competition for scarce resources, low per capita availability of productive land, remoteness and marginalization have increased vulnerability in terms of food security, primary healthcare, natural hazards, and access to services and productive land resources. Today, the region is characterized by an increased incidence of social and political conflict, poverty, and environmental degradation (Jodha, 1995; Pant, 2003).

2.2.1. Biophysical vulnerability and mountain "niche"

Mountain environmental changes occur through a combination of biogeochemical processes. A mountain represents the areas of hazard, vulnerability, and risks (Chalise, 1994). Mountains are very attractive to outsiders, but not easy places in which to live. The force of gravity and the erosive power of water have shaped landscapes into complex topography and diverse microhabitats in mountains. Slope, aspect, and altitude determine the fundamental characteristics of mountain habitats. Topographic diversity adds to the small-scale variations in physical environment. Geographically, latitude (distance from the equator), continentally (distance from oceans), and topographic features (direction and altitude) affect climate and local weather patterns, rendering some mountains almost permanently wet, others dry, and still others highly seasonal. Geological conditions add dimensions of diversity and influence soil development, soil type, erosion processes, and vegetation cover. Climates vary according to altitude and exposure; thus, mountain habitats have greater species richness than the lowlands when comparing similar areas. This richness decreases with increasing altitude, but isolation and environmental extremes restrict species' habitats. Biogeographically, the Himalayan region is stratified into elevational belts, each with a characteristic flora and fauna, including the 'montane' belt (below the treeline), the vegetation-covered 'alpine' belts, and the snow and permafrost covered 'nival' belt (Körner, 2004). The Himalayan region is predominated by the Asia monsoon climate, which is characterized by a high rate of seasonal and interannual variability and distinct climate regimes, together with great geophysical variability and altitude as well as longitude/latitude gradient. All great geophysical fragility and climatic variability are strong forces imposing on an ecosystem. Therefore, the variability of ecosystems and land use in mountain regions shows close linkage with a monsoonal climate, altitude, and mountain fragility, which predetermines the pasture in the high plateau, terraced agriculture in midmountain, and forest-based shifting cultivation in the humid tropics. The Himalayan landscape and biota have undergone some transformation through their human use for hundreds of years.

2.2.2. Socioeconomic vulnerability and resilient societies

Despite the harsh environment, more the 500 million people, made up of about 100 ethnic/tribal groups, live in these mountains. Most of them inhabit middle mountains; almost all live in poverty and are considered highly vulnerable to food insecurity. However, they have a significant impact on larger populations living in lowlands through their influence on land and resource use. Mountain landscapes are quite heterogeneous, often a mosaic of forests, wetlands, rangeland, and cropland. There is a range of habitats for all life forms and a diversity of livelihoods: from nomadic to agro-pastoral (usually high altitude above 3000 m); from sedentary upland agriculture (less than 3000 m) to terraced paddy (less than 2500 m); from shifting cultivation (less than 2000 m) to tea garden (less than 1500 m); and from hunting and gathering to home garden and aquaculture, or composite livelihoods, which are well adapted to diverse mountain habitats (Xu and Rana, 2005). Due to the high malaria incidence in the lowland tropics, mountain habitats were ideal for many indigenous people in the past. There are many historical examples of flourishing mountain economies based on mountain habitats, including those of the Tibetans in China, hill tribes in India, and the indigenous people in Nepal. Many of these cultures still survive and in some cases even thrive. Mountain towns, together with caravan trade networks, have linked mountain with lowland for centuries. For example, merchants from the Yunnan Province of China in the eastern Himalaya traveled to the Tibetan plateau, Southeast Asia, and South Asia for a thousand years. Mountains were as much pathways of migration and trade as barriers between highlands and lowlands (Pereira et al., 2005). Lowland economies have generally dominated, however, because of intensive sedentary agriculture, manufacturing based on larger scales, easier transportation and trade, urbanization and the associated development of education, healthcare, and political power. Nowadays, globalization has brought further environmental crisis and economic polarization of mountain people and outsiders. Mountain people are more vulnerable to longer periods of drought, and more frequent flash floods due to climate change. Mountain people receive fewer social services (such as education and healthcare services) and development support for infrastructure (such as water, sanitation, roads, and telecommunications) from the state. Mountain communities are also insufficiently recognized as rich reservoirs of indigenous knowledge and cultural resources. Environmental degradation, poverty, and out-migration become inevitable features of the social landscape of the mountains (Shrestha, 1989; Korner et al., 2005).

2.2.3. Land use history and political ecology of landscape transformation

Land use history in the Himalayan region reflects the linkages between settlement history, cultural ecology, and political economy as these relate to resources, marginality, and territory (Zurick, 1989). Land use changes are responses to changes in the provision of ecosystem services and socioeconomic access (Salick et al., 2005). Historically, mountain livelihoods have been based on a mixture of hunting, gathering, cropping, and animal husbandry across altitude and latitudinal gradients for different people and households, even composite farming of swidden-fallow field, terraced paddy, home-garden, and cash cropping for individual farmers. This mixture varied in composition with time, place, and culture. The harsh and unpredictable climate combined with changing socioeconomic and political factors has forced mountain inhabitants to be flexible and mobile in land use. Exchanges of products between and among different ethnic groups and between highland and lowland groups are common.

Mountain people share a steep uneven physical terrain and are embedded in an even steeper and unequal political environment. They interact with the states that govern them within highly unequal power relations. When analyzing land use changes, it is very important to recognize that land use and property rights in the Himalaya have always been greatly influenced by political perspectives and ideologies. The power bases of land use decision making are lowland urban areas. Generally, mountain regions are perceived as sources of potential resources; consequently, logging, mining, plantation, and hydropower have been operated by state-owned or private enterprises for the benefit of the lowlands. Traditional land use practices such as shifting cultivation and nomadic herding are often negatively portrayed as responsible for deforestation and desertification in the highland leading to downstream flooding, rather than being viewed as a sustainable land use (Ives, 2004). In the case of Nepal, political power is based in the Kathmandu valley in the hands of midhill elites. Before 1957, the Nepalese government's focus was on conversion of forestlands to farmlands, and extraction of timber for export for the interest of the state (Gautam et al., 2004). In lowland Terai, deforestation has predominantly been caused by the demand for agricultural land and forest products from settlers who migrated to the region from the mountains after malaria was eradicated in the early 1960s (Chakraborty, 2001). As a result, traditional systems of resource protection do not exist; social conflicts increase while there is inequality of access to land and forest resources. Governments in the region often respond through further privatization of the common resource, such as forest, water, or rangeland resources rather than support for better infrastructure and social services (Yan et al., 2005).

3. Key lessons from land–health linkage

3.1. Environmental health risk

The mountain environment is rich in mineral resources, but also carries potential risks. The environmental health risks in the mountain include the endemic diseases linked to heavy metals (Purohit et al., 2001) and high-level toxic minerals such as fluoride (Rajasthan, 2001; Alarcon-Herrera, 2001; Gikunju, 2002), arsenic (Maharjan et al., 2005) and thallium (Xiao et al., 2004). The contaminant convergence is associated with mountain terrain, steep slope, and sediment transportation and trapping. Human activities have greatly contributed to increasing exposure to health risk, such as with extraction of groundwater and coal mining in fluoride-rich geology. A case study in

Yuanmou County, Yunnan Province of China, shows that local farmers depend on underground water for drinking and irrigation, where fluoride content in underground water ranges from 1.0 to 7.2 mg/L (44 samples higher than 1.0 mg/L in a total of 860 water samples collected in the valley). By sampling from a total population of 40,686 in 43 villages, we found that more than 33.3% had permanent teeth with a history of dental caries (authors' own field work).

Arsenic contamination of groundwater has been recognized as a major public health problem in Nepal (Maharjan et al., 2005), which has various acute and chronic effects on human health. Poor access to environmental status information and improper land use management results in great health risk (Victor and Reuben, 2000). The land use transitions adding to well known natural processes like weathering of rocks and biological activities are the dominant natural processes of arsenic release in the environment; whereas smelting of nonferrous metals, manufacture of various arsenic compounds, burning of fossil fuel, incineration of arsenic-containing substances and the extensive use of arsenical pesticides, fertilizers, herbicides and pharmaceuticals are anthropogenic causes of the release of arsenic into the earth's environment. On the other hand, well-functioning ecosystems can absorb and remove contaminants. For example, wetlands can remove excess nutrients from runoff, preventing damage to downstream ecosystems (Jordan et al., 2003).

3.2. Sedentarization in alpine rangeland and tropical forest ecosystem

Two groups that can be distinguished are agro-pastoralists in the semiarid areas of the Tibetan Plateau and shifting cultivators in the tropical forest of the south-facing Himalaya. Throughout the Tibetan region, the traditional way of life—nomadic pastoralism with seasonal mobility—has been developed over hundreds of years and Tibetan herders have acquired an intricate traditional ecological knowledge of their natural environment. A wide variety of livestock and a flexible and opportunistic approach for searching for greener pastures and water resources have enabled them to survive in the extremely harsh environment. Nomads often face a different spectrum of health problems than do others due to a transient-basis of human settlement, mobility in land use, and poor access to heath care services (Sheik-Mohamed and Velena, 1999). For Tibetan nomads, water access and supply is a crucial issue. Water is also an essential part of land cover and land changes and is, of course, essential to health. Foggin et al. (2006) finds the connection between high rates of miscarriage and infant loss for Tibetan nomadic women with their overburden of labor, the significant link between general morbidity, and the time it takes to obtain water. Infectious disease prevalence in pastoralists differs from settled populations with a profile that is directed toward diseases that have a reservoir in cattle, such as tuberculosis or brucellosis, and those that require long-term treatment, such as some sexually transmitted diseases and again tuberculosis (Niamir-Fuller and Turner, 1999). Infections, like leprosy or tuberculosis, which require long-term treatment and management, are difficult to target in nomadic populations in mountain regions.

Despite the mobile lifestyles and flexible livelihoods, strategies can allow land (both pastures and forest) to 'rest' seasonally and thus curb overgrazing or overharvest. Sedentarization, or the attempt to settle migratory peoples permanently in terms of land use, property, and settlement, is perhaps the oldest and most continuous project of states (Sahlins and Scott, 2001; Xu et al., 2007). Mobility in land use is shrinking as farmers push further into marginal lands and herders settle more often around infrastructure for water, health, and education (Ellis and Swift, 1988; Niamir-Fuller, 1999). Access to large and diverse landscapes is critical to maintaining productivity of livestock in pastoral systems and reducing vulnerability of pastoral families, particularly during drought. Recent privatization and sale of pieces of pastoral rangelands by pastoral peoples has been aptly termed 'selling wealth to buy poverty' (Rutten, 1992). In the mid-1990s, the Chinese government aimed to privatize the rangeland through long-term contracts, either with individual families or groups (Yan et al., 2005). All rangeland for winter grazing is supposed to be allocated to individual households over the next two to three years while summer pastures at high altitude will be allocated to villages or groups of households. In fact, enclosed privatization, despite the state's modernization drive, is not the preferred option for most herders, according to villagers. Shared labor for herding is still a common practice. Sedentarization in transition to a market economy, on the other hand, leads to social stress, boredom, and reduced physical activity. With increasing barley production, there is also a significant increase in the consumption of barley wine or local alcoholic drink. Debilitating diseases, including hepatitis, tuberculosis, gallbladder and heart diseases, and peptic ulcers, are commonly reported by local Tibetan herders and health workers (Xu et al., 2007).

Long-fallow, rotational shifting cultivation ("swidden agriculture") is one well-documented example of how mobility and flexibility underpin the sustainability of extensive smallholder systems (Conklin, 1957; Ramakrishnan, 1992; Xu et al., 1999; Yin, 2001). If these attributes are lost, such systems may collapse. Hunter–gatherers (such as the Dulong in Yunnan and the Nagas in Northeast India) in the human tropics may have more diverse diets, and nomads on the Tibetan Plateau have a higher protein intake, and therefore may have nutritional status different to sedentary farmers. The diet of subsistence farmers appears to be comparatively well balanced, even when they are lean. In mountain ecosystem, hunter–gatherers, shifting cultivators, farmers, and herders use mobility as a strategy to access food and water resources and maintain good health and health ecosystem over time. Policies need to provide mobile services to mobile communities to allow them to maintain good health care and educational opportunities while they move livestock to seasonal pastures. Sedentary lifestyles might increase certain diseases such as parasites. Similar observations imply that intestinal infestations are commonly more severe in sedentary populations than in their more mobile neighbors. There is also direct evidence of an increase in pathological intestinal bacteria and intestinal parasites with the adoption of sedentism. The advantages of sedentism may have been offset by risks associated with increased infection, closer spacing, or the substitution of starchy gruels for mother's milk and other more nutritious weaning foods. The intensification of agriculture and the adoption of more sedentary lifestyles may not have improved the probability of surviving childhood in the absence of increased access to a health care system.

3.3. Intensification in cultivation

Agricultural intensification—defined as higher levels of inputs (high yield varieties and chemicals) and/or increased output (in quantity or value) of cultivated or reared products per unit area and time—permitted the doubling of the world's food production from 1961 to 1996 with only a 10% increase in arable land globally (Tilman, 1999). Such achievements are viewed skeptically by observers contemplating the future of agriculture in the Himalayan region where intensification may be considered as environmentally untenable (Abrol and Sangar, 2006). Intensification may lead to loss of agricultural diversity (Xu and Wilkes, 2004), soil and water degradation (Brown and Shrestha, 2005), and negative health impacts including poor nutrition, increasing pollutants, and infectious diseases such as malaria (Tyagi, 2002) owing to special biophysical constraints and socioeconomic conditions that inhibit mountain farmers' (especially smallholders') access to input factors such as new technology, roads, and markets (Salick et al., 2005). Agricultural intensification is a complicated issue, which is not simply driven by population, but by political economy. Matson et al. (1997) explicitly equate today's intensification with a cash crop and plantation economy, inorganic fertilizers, and pesticides, and deem it unsustainable. Intricately linked to land use, agricultural output growth, food security and land transformation, in particular, over the past half-century, are human health concerns originating from the widespread usage of biocides (pesticides, fungicides, insecticides, larvazides) and chemical fertilizers (Nosengo, 2003). The application of these biocides and fertilizers triggered large-scale land use intensification and agricultural output growth worldwide in general, and mountain regions in particular, thus contributing to food security, but it also implied negative health consequences for the poor mountain farmers who have neither proper knowledge nor good access to health care services. On the other hand, food security does not always achieve dietary diversity and balanced nutrition for humans. The environmental consequences of input mismanagement and overuse include the destruction of beneficial insects, water logging and salinization of irrigated land, pollution of groundwater and rivers, poisoning of farm workers, and excessive dependence on new improved crop varieties. Investigation estimates that almost half of the nitrogen spread onto fields is not taken up by crops, but instead washes away into forestland, wetlands, lakes, and rivers. The over-fertilized trees are now growing faster than normal, and the levels of various nutrients in the foliage have changed, the leaves contain more nitrogen and less calcium and magnesium than in normal trees, and about 10% of the added nitrogen is now leaking out of the forest as nitrate in groundwater (Nosengo, 2003). In China, for example, nitrate levels are already well above the WHO standard for public health risks, and these may well double over the coming half-century. Health problems comprise the spread of infectious and chronic diseases, which are exacerbated by the impacts of biocide usage through the collection of agricultural chemicals in irrigation canals and drinking water (Geist, 2005).

Related health problems are reported from various dryland ecosystems in the Himalaya that have undergone rapid land use intensification in order to achieve national self-sufficiency in food or basic material needs for industry. Rice and cotton are the key irrigation crops in the drylands of the western Himalaya, such as the Xinjiang Province of China, India, and Pakistan. Through intensification measures related to food security, trade-offs exist between food provision, shelter and clothing, and the degradation of highly fragile dryland ecosystems, sometimes referred to as desertification. Although the intensification of agriculture expanded production, it may have increased risk in both natural and cultural terms by increasing the risk of soil exhaustion in central growing areas and of crop failure in marginal areas. Such investments as irrigation to maintain or increase productivity may have helped to protect the food supply, but they generated new risks of their own and introduced new kinds of instability by making production more vulnerable to economic and political forces that could disrupt or distort the pattern of investment. Similarly, specialization of production increased the range of products that could be made and increased the overall efficiency of production, but it also placed large segments of the population at the mercy of fickle systems of exchange or equally fickle social and political entitlements.

3.4. Habitat modification and development displacement

Humans have been transforming natural landscapes into cultural and productive landscapes for millennia. Mao's War Against Nature (Shapiro, 2001) showed how the Chinese state mobilized to build dikes, drain water, fill earth, and convert roughly 25 square kilometers of wetlands into grain fields in Dianchi Lake near Kunming, for land reclamation in 1970, with a military-style campaign. With technology advances for drainage and malaria control, many Nepalese eventually came down from high altitudes to lowland terai to transform large forest frontiers into productive agricultural land (Shrestha, 1989; Chakraborty, 2001). The large-scale drainage of wetland, swamps, and lakes successfully reduced the health risks of malaria and schistosomiasis, but also contributed to the ecosystem imbalance that has afflicted local and further-downstream communities. The environmental impacts of globalization cannot be ignored (Ehrenfeld, 2005). Dams and irrigation systems were one of the most visible symbols of economic development and primary drivers of land cover and land use changes and fragmentation in the twentieth century (Wu et al., 2003). Building the Three Gorge Dam along the Yangtze River resulted in the resettlement of one million people from their original habitats. Irrigation and dam construction increased water-related diseases such as schistosomiasis, Japanese encephalitis, and malaria (WCD, 2000). There is an extensive literature on disease outbreaks in the aftermath of large-scale water resource development, although a lack of comparative data on the burden of disease estimation and its economic cost. Similarly, it is estimated that small dams have an equal or greater impact on human health than do large dams due to a high degree of water contact with people and animals (Patz and Confalonieri, 2005).

3.5. Migration, land use and HIV/AIDS

Population growth might not be the prime driver of ecosystem destruction as the public and many scientists assume (Tiffen et al., 1994; Xu et al., 2005). Moreover, when population growth does drive land use and land cover change, it often does not lead to destruction of productive capacity. Whether population growth does matter or "does change" land or not, regardless of positive or negative interpretations, much depends on the local political economy. Population growth generally traces back through causal chains to other factors, such as state policy and the local economy. Population growth might contribute to agricultural expansion and intensification and/or technical innovation. China and India have experienced soaring birthrates and sharp population growth for several decades. Governments are having trouble dealing with feeding, housing, and educating an increasing number of children, at the same time confronting the falling water tables, deforestation, and soil erosion that rapid population growth brings. In these conditions, any new threat from infectious diseases, drought, or famine can become a full-blown crisis.

Economic liberalization and globalization promotes migration, which has potential application to land use transition and human health. Seddon et al. (2002) estimate that the remittance economy contributes a total of between 13% and 25% of the national GDP of Nepal on the one hand, while on the other hand, outward migration from rural mountain areas has left the population with insufficient manpower to sustainably manage natural resources. Young men and women, who are the major workforce, migrate out to seek employment opportunities and a better life. Economic connectivity and increasing migration have resulted in increasing HIV/AIDS. The link between movements of people and the spread of the AIDS virus has been acknowledged. Lorry drivers, plantation and mining workers, drug-users and traffickers, prostitutes, construction workers, and traders are among the groups at high-risk of HIV infection. The HIV/AIDS virus has hitchhiked along the transportation corridors in transboundary areas of Mynama–Yunnan of southwest China and India–Nepal. The land use changes in the mountain areas, including conversion into infrastructure development, tourism recreation, plantation, and mining, have contributed to the increasing risk of the spread of STDs and HIV. The increase of HIV infection in rural adult populations due to rural–urban migration and improved transportation and market connection, has become a major issue in the rural areas of China, India, Bangladesh, and Nepal and in the remote areas in Myanmar. Disease is far from the only threat to overburdened societies. United Nations' projections show India's population may increase by 600 million more people by 2050, which will alter the land cover and land use and further increase ecological footprints in the mountain ecosystem. There is a clear case of stagnation and involution of agriculture in the face of land stress linked to increases in population (Turner and Ali, 1996).

3.6. Biocultural diversity and nutrition

There is an inextricable link between biological and cultural diversity that emerges from historic ties to diverse landscapes (Xu et al., 2005a). Biodiversity directly links with human health in many ways. (a) Biodiversity plays a crucial role in controlling disease "vectors" and microorganisms, therefore a declining biodiversity may play a significant role in the current emergence, resurgence, and redistribution of infectious diseases in animal and plants (Epstein et al., 1997). (b) Biodiversity can translate into food dietary diversity and nutrition (Johns and Sthapit, 2004), traditional healing systems, and new drug discoveries for the treatment of infectious diseases. (c) Biodiversity also underpins the ecosystem-level processes (such as large predators) and resilience of the ecosystems (vegetation regeneration and ecosystem restoration).

Predator/prey relationships are central to biological control. Owls and snakes help regulate populations of rodents in the grassland—opportunistic species involved in the transmission of Lyme disease, hantaviruses, arenaviruses, leptospirosis, and human plague. Freshwater fish, reptiles, and bats help limit the abundance of mosquitoes, some carrying malaria, yellow fever, dengue fever, and many encephalitides. Rodents, insects, and invasive species represent key biological indicators rapidly responding to environmental change (Epstein et al., 1997).

Diversity and health are linked also to agriculture, where monoculture cropping has been associated with increased vulnerability to acute food shortages and longer-term nutrient deficiencies (Waltner-Toews, 2001; Altieri, 2002). Decreased dietary diversity is one factor contributing to malnutrition (Johns and Sthapit, 2004). Subsistence farmers, who either do not consume, or consume little modern refined foods, appear to enjoy several nutritional advantages over more affluent modernized groups that protect them from many of the diseases such as obesity, diabetes and heart disease that now affect urban society.

Loss of biodiversity is occurring at an unprecedented rate in the mountain habitat, driven by over-exploitation, land cover and land use changes, global warming, and invasive species and large-scale infrastructure development (Xu and Wilkes, 2004). This depletion and extinction of biodiversity and degradation of ecological landscape threatens not only the vital ecosystem services but also the cultural services. The loss of cultural ties between people and ecosystems often leads to a loss of cultural identity, causing increased social disruption and stress that in turn causes a whole array of mental and physical health effects (Xu et al., 2005a). The loss of traditional knowledge systems also has negative health effects, notably through plant medicine that might help humankind deal with pandemics like AIDS, cancer, diabetes, and other modern health problems in a globalizing world (Cox, 2000). Traditional ecological knowledge systems for land management, traditional food systems for dietary and nutrition, and traditional healing systems for heath care are equally important to human health. The history of colonization shows clear links between losses of cultural diversity and identity and increased rates of disease and premature mortality (Kunitz, 1994).

3.7. Mountain hazards and floods

Intense seasonal precipitation in the central and eastern Himalaya during the monsoon months (June–September), and in the western Himalaya during winter, triggers various types of natural hazards in different elevation zones (Xu and Rara, 2005). Snow avalanches and glacial lake outburst floods predominate at very high elevations (>3500 m), while landslides, debris flows, and flash floods are common in the middle mountains (500–3500 m). Mountain disasters are often triggered by land use and land cover changes, such as dam building, road construction, and deforestation. Floods and landslides are the principal hazards in the lower valleys and plains. During extreme weather events, the consequences are disastrous. Hundreds of lives and billions of dollars worth of property and investment in high-cost infrastructure are lost in the region every year due to landslides, debris flows, and floods, along with the destruction of scarce agricultural land.

In the case of flash floods, such as a glacial lake outburst flood (GLOF), there are health components related to both before and after an event actually has happened. Before an event, those communities that are living downstream from a glacial lake that has been determined as being in danger of breaking its dam and causing an outburst flood, constantly have to live with the risk (Mool et al., 2001). This continuous risk may cause long-term stress, which may seriously affect people's health and well-being—how do you sleep when your house is in constant danger of being washed away at any time (Eriksson, 2006)?

During and after a flash flood or GLOF, there are a number of factors affecting human health (Eriksson, 2006). The floods themselves may cause deaths and injuries among the population. Vulnerable groups, such as the poor and lower castes, are often hit hardest because these groups often have their homes in more exposed, less protected, areas or are marginalized in other ways (Gardner and Dekens, 2006). Moreover, as it is chiefly communities in the rural areas that are in danger of being struck by floods, distances to hospitals may be considerable and further aggravate the results of the physical damage to humans. After a flash flood, local communities are often left with severe damages to property. Agricultural fields, livestock, and houses may have been swept away or damaged. This may leave a large proportion of the population in the affected villages without a source of income. If their land and property have been washed away, many people have to be resettled. All these cases may lead to socioeconomic stress, which may pose a serious health problem for those affected, although this negative effect on human health resulting from extreme events seldom is highlighted. As an example of long causal chains, environmental changes affecting river flows and riverine floods might lead to disputes over water rights and access to hydrological information. The connections between ecosystem functioning and human health may be bidirectional.

3.8. Climate change and human health

Climate change constitutes an additional pressure that could change land use (Kalnay and Cai, 2003; Pielke, 2005) and food security (Parrya et al., 2004), therefore altering ecosystem services with significant impacts on socioeconomic systems (Winnett, 1998). The combined effects of climate change on the physical environment, ecosystems, the economic environment, and society, directly affect health. Periods of ecological and climate change may be associated with extinctions of some species and the emergence of new ones (Pimm et al., 1995; Parmesan, 2006). These periods of change are also likely to affect agricultural production and vegetation productivity, with some of the cereal crop yields and plant growth expected to increase at high latitudes (Ramakrishna et al., 2003; Parrya et al., 2004). Long-term changes in world climate may affect many requisites of good health, such as availability of sufficient food, safe and adequate drinking water, sanitation, and secure dwelling.

In addition, the distribution and seasonal transmission of several vector-borne infectious diseases (such as malaria, dengue fever, and schistosomiasis) may be affected by climate change (Sutherst, 1998; Sutherst, 2001). Altered distribution of some vector species may be among the early signs of climate change that may affect health. Pests, pathogens, and parasites may be among the first to emerge during some of these transition periods. A change in world climate could increase the frequency and severity of extreme weather events. The impacts on health of natural disasters are considerable. The number of people killed, injured, or made homeless from such causes is increasing alarmingly. The vulnerability of people living in risk-prone areas is an important contributor to disaster casualties and damage. An increase in heat waves (and possibly air pollution) will be a problem in urban areas, where excess mortality and morbidity is currently observed during hot weather episodes (WHO, 2000).

4. Ecosystem approach to human health: an imperative

Land use transition driven by the local political economy and globalization has profound impacts on human health. What are the relationships between land use transition and human health? Answers to this question are multiple and boundless, but to illustrate the relationships, let us note: herders, farmers and fisherfolk are active managers of the ecosystems' capacity to deliver services through land use activities (Folke et al., 2005). Researchers began to work with local people and health workers to develop local health predictors, indicators, and feedback mechanisms, including nomadic lifestyle, literacy, mobility, alcohol use, and access to water, and foraging for Tibetan nomads (Foggin et al., 2006). An ecosystem approach to human health favors a combination of biophysical and social indicators (e.g., ecological footprint, access to land and water, natural capital stocks, ecosystem health, healthcare, education, access to market and information) to monitor the health of ecosystems (Rapport and Singh, 2005), human behaviors, and physical and psychological health (Dovers et al., 2003; Naveh, 2000). It also insists on collaborative indicator building processes together with stakeholders, including local people, resource managers, and health practitioners, which leads to nonlinear responses. Time scales of system interactions among ecosystem, pathogens, humans, and the environment are different and often more rapid in the contemporary world of global change than comparable evolutionary factors causing nonlinear responses of disease vectors and pathogens. Conventional infectious diseases such as tuberculosis (TB), schistosomiasis, and malaria reemerge due to the evolution of new strains of pathogens and alteration of habitats. The emerging of new diseases such as HIV/AIDS and avian flu is also related to interaction between humans and ecosystems including wildlife and livestock (Capua and Alexander, 2002). Chronic diseases such as diabetes and depression are often related to changes in lifestyle and social environment. Human actions can promote persistence of the ecosystem's services that would not persist in the absence of people, so that the human component causes nonlinear responses from ecosystems. Human responses allow for more rapid recovery (response) of degrading systems such as dryland and forestland, by altering the trajectory from negative feedback. Human systems can have major long-term effects on biota and physical systems that may not be predictable for some short-term analyses. Therefore, the emergence of EcoHealth as an open approach refers to study of the dynamic relationships among peoples, ecosystem, and human health in the socioecological environment. EthnoHealth is transdisciplinary (Lebel, 2003) with representatives from biology, ecology, public health, cultural anthropology, sociology, economics, gender studies, geography, nutrition, epidemiology, governance, political science, environment studies, natural resource management, conservation, and sustainable development. An inclusive vision of ecosystem-related health problems involves each discipline in a process that allows researchers to exceed the limits of their own disciplines to generate new frameworks, new methods, and new institutions born from synergistic collaboration. The diversity and dynamics in the transdisciplinary learning process permits a focus on complex interactions among the various ecological and socioeconomic components of coupled human–environment systems rather than resorting to simplified quick-fix and sometimes expensive means of tackling complex problems, such as the use of DDT as a silver bullet to fight malaria (Lebel, 2003). Many models of natural resource management assume linear relations that are not applicable to the complexity of interactions of ecosystem and human health. There is a need to integrate economic, social, and ecological models to address issues such as land use transition and health, water quality and allocation, and climate change in a more realistic and nonlinear approach. On the other hand, tremendous efforts have been made to improve land and water resource management, such as eco-agriculture for agribiodiversity and livelihood and organic farming for human health and food safety (McNeely and Scherr, 2003). Controls that drive social, cultural and political systems are typically not included in ecosystem system interactions. Amartya Sen (Sen, 1981) highlights the central role of institutions—regularized patterns of behavior between individuals and groups (rather than organizations) in society—in mediating human–environment relationships for the study of poverty and human well being. The concept is developed further by Leach et al. (1999) as environmental entitlements that characterize the range of management strategies adopted by farmers in the Himalaya region as they respond to intensified agriculture, and in turn the implications of these changes for future health, livelihoods, and landscapes. There are two basic concepts in Sen's entitlement approach: endowments and entitlements. Endowments refer to the rights and resources that social actors have, such as land, water, labor, and skills.

Entitlements refer to legitimate effective command—both formal and informal—over alternative commodity bundles based on the exercise of endowments. The process of transforming endowments to entitlements is critical to enhance the capabilities of a local community (Sen, 1981). It is essential to examine interactions between science and policy by describing the key lessons from the science of land use and human health linkage that can be relevant to policy. The type of science that successfully links with policy makers is credible, salient, and legitimate (Cash et al., 2003). Effective links between policy makers, local communities, and scientists will reduce the risk of unexpected changes in unexpected places, and strengthen the entire process of land and water or integrated natural resource management (Lebel, 2004; Jodha, 2005; Reid et al., 2006). Securing access and property rights is another policy instrument for transforming vulnerability to sustainability. Finally, we need to overcome the institutional barriers to the EcoHealth approach, as both the health and environment are vertically organized around conventional disciplines and organizations. Implementing an ecosystem approach to human health requires a change in the overarching institutional paradigm and a focus on horizontal integration and cooperation in a transdisciplinary manner.

5. Conclusion

Healthy ecosystems and good health are vital to the continued “virtuous cycle” of coupled human–environmental systems. On the other hand, where there is environmental disruption leading to poor health and therefore poverty, there may be compounding effects and establishment of “vicious cycles” (Woodward et al., 2000). For example, land degradation and soil loss lead to crop failure, famine, and health problems. These health problems will more likely be experienced by women and children first, and, as such, can affect not only current but future health through poor growth, increased disease burdens in later life, and lower productivity. The changes in the physical environment affect the subsistence economy, resources becomes scarce, and the consequent struggle for bare minimum needs poses a threat to the health of the community, especially the women of the community (Reddy, 2004). However, there are also effects in the other direction: populations with high levels of chronic health problems can put less energy and time into growing crops, preventing erosion, and managing land and water resources, leading to decreased sustainability.

Ecosystem approaches can prevent disease emergence (Lebel, 2003). Controls in disease vectors can also contribute to the functioning and structure of ecosystems. The difference between direct and indirect effects applies to the temporal and spatial scales over which these effects occur. One result is that effects of ecosystem disruption on health are often displaced geographically. The cost of rich countries’ overconsumption on climate change is a good example, in which many of the adverse health effects are likely to appear first in low carbon-emitting countries such as the Himalaya, or postponed, as in the long-term consequences of climate change or desertification. The links between land use transition and human health are seen most clearly among impoverished communities, who lack the “buffers” that the rich can afford. Owing to the many intermediate factors that may be involved, there are frequently considerable time lags between ecosystem change and health outcomes. For example, loss of biodiversity may lead to higher mortality and morbidity by means of diminishing supplies of biopharmaceuticals, but this would be apparent only after some years. In terms of spatial scales, we are most familiar with local effects (such as flooding and mudslides on steep denuded hillsides). More difficult to identify, but perhaps even more important for human health in the long term, are the impacts of socioeconomic transformation of the landscape in mountain ecosystems in light of regional and global climate changes, including biogeochemical cycles, hydrologic processes, and landscape dynamics. Ecosystem approaches that link land use transition and human health define important pathways of feedback from coupled human–environment activities at the local and regional scale in the Himalaya, with global significance. However, there is a need for greatly improved understanding of how human actions affect the natural processes of the mountain ecosystem services, and an even greater need to evaluate the consequences of these changes on the human health of indigenous people.

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