An Assessment of Risks and Threats to Human Health

Associated with the Degradation of Ecosystems

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FOREWORD

Ecological systems provide humans with products and services essential for good health and survival. Ecosystem degradation by humans has increased the risks and threats to our human health. In recent years, there has been a growing interest by the scientific, business, industrial and civil society communities with regard to the potential links between the collapse and degradation of an ecological system and its impacts on human health.

On December 8, 1998, in Washington D.C., the Division of Environmental Information, Assessment & Early Warning (DEIA&EW) of the United Nations Environment Programme (UNEP), convened a meeting of experts to discuss issues related to Early Warning of Emerging Environmental Threats.

One of the issues identified was the potential risks and threats to human health due to degradation or a collapse of an ecosystem. In consequence, UNEP conducted this study to assess the status of and identify scientific knowledge about this subject. The report attempts to explain the consequences of environmental change and deterioration of ecosystems on human health and analyzes global, regional, and national trends. The study also seeks to provide a rational basis for decision-making in the formulation and implementation of environmental policy.

The analysis indicates that most of the health impacts linked to degradation of the Ecological System result from a combination of environmental processes that create conditions conducive to diseases. Invariably there are intermediaries connecting the change in the ecosystem and human health.

The report does not make any judgements about, nor does it attempt to provide direction on, how to resolve human health problems. It is however, becoming clear that there is a need and an opportunity to address emerging global and regional health concerns resulting from environmental degradation.

Daniel van Claasen,
Acting Director

Division of Environmental Information,
Assessment and Early Warning, UNEP

"A healthy population and a healthy environment are (a) social and economic good. We cannot think of a healthy population without a healthy environment and ecosystem."

Klaus Toepfer,
Executive Director

United Nations Environment Programme

(Third World Health Organization. The Ministerial Conference on Environment and Health, London 16-18 June, 1999)

1. INTRODUCTION

The health and well being of humans cannot be separated from the natural environment. Many of the threats to human health are an intrinsic part of ecosystems. The challenge lies in maintaining people's health while simultaneously improving the health of ecosystem sas a whole.

The total impact of a transformed environment causes considerable harm to natural life support systems and a threat to the sustainability of human health (Rapport *et al.*, 1998). The environmental threats to human health can be divided into two main categories: (1) lack of development — inability to cope with natural hazards and/or lack of access to essential environmental resources, and (2) unsustainable development — ecosystem degradation (WRI, 1998). Major causes of environmental changes, as well as characterization of environmental hazards, i.e. biological, physical, and chemical, are critical items to be analyzed.

The goal of this study is to establish whether there are strong and direct links between ecosystem degradation and human health. The main objectives of this report are: (1) to review key emerging and re-emerging threats to human health at global, regional, and local levels due to ecosystem degradation; and (2) to establish causal linkages between ecosystem degradation and human health. Environmental conditions that foster the transmission or spread of disease, exposure to harmful chemicals, or hazardous physical conditions have been reviewed. This study also intends to raise public awareness about the critical need for a more holistic understanding of the links between ecosystem well-being and human health.

By synthesizing the information from different sources, this report provides an overview of the recent findings surrounding the linkages between environmental change and population health. This review intends to establish a basis for a global data collection system, as well as promote the idea of the inter-relationships between human health and the state of the ecosystems, by compiling examples and grouping them in accordance to specific regional natural conditions and ecological characteristics.

2. ENVIRONMENTAL DEGRADATION

An ecosystem is a functioning unit of nature that combines biotic communities and the abiotic environments with which they interact (LaRoe *et al.*, 1995). There are three main features characterizing a healthy ecosystem: vigor, resilience and organization. A healthy ecosystem is a sustainable component of the biosphere that has the ability to maintain its structure (organization), and function (vigor) through time and in the face of external stresses (resilience) (Mageau *et al.*, 1995). Healthy ecosystems provide support to the human community, such as food, shelter, the capacity to assimilate and recycle wastes, clean air and water. Still, there is a certain difficulty in defining ecosystem health given the qualitative and quantitative differences among ecosystems. For instance, there are ecosystems in which rich biodiversity is a sure sign of health and in others it is

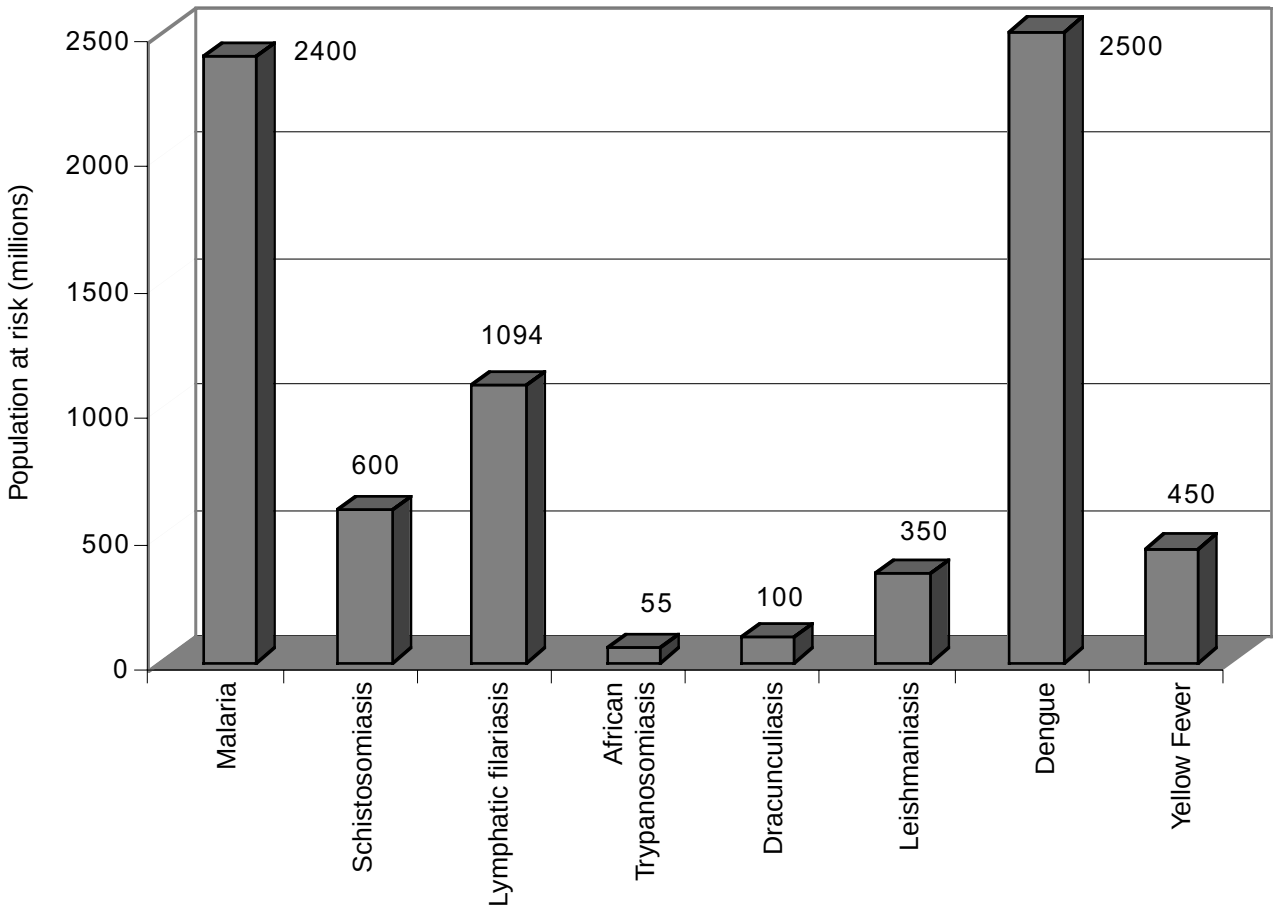

Figure 1. Major tropical vector-borne diseases as a result of climate change.

(Source WHO, 1996)

a sign of disturbance (Enhrenfeld, 1995). From a global perspective the environment has continued to degrade during the past decade. According to the Global Environment Outlook Report 2000, different regions in the world experience various environmental concerns (UNEP, 1999).

Humans have modified approximately 50 percent of the land surface, account for more than 20 percent of the atmospheric carbon dioxide concentration, utilize over 50 percent of the accessible surface fresh water, and are responsible for about 60 percent of all nitrogen fixation (Rapport, 1998). The total impact of these modifications are a significant danger to the favorable functioning of the natural life support systems, which are the major part of the ecological systems, and to the sustainability of the population health. The combination of environmental changes that creates the conditions leading to disease occurrence is also of a significant concern here.

Human activities are directly responsible for creating agroecosystems and cultural landscapes at the expense of many natural communities and the reduction in ecosystem services. With current rates averaging about 0.7 percent per year, serious loss of forest quality and old-growth habitat in many temperate and boreal forests due to pollution and tropical deforestation are problems of a significant concern.

Desertification and drought are problems of a global dimension that affect more than 900 million people in 100 countries. Twenty five per cent of the Earth's land area is being affected by land

degradation. Desertification is occurring in 30 percent of irrigated areas, 47 percent of rainfed agricultural lands and 73 percent of rangelands. Hydrological and ecological functions of over one-half of all wetlands have been altered due to encroachment. Global freshwater biodiversity is declining significantly. Today about one-third of the world's population is living under moderate to severe water stress, most notably in Middle Asia and North Africa. Coastal water is being contaminated by land-based sources, particularly by municipal wastes that cause eutrophication. Many fishery resources are classified as overexploited. Red tides have increased in distribution and frequency. Stratospheric ozone has decreased since 1979 by about 5.4 percent at northern mid-latitudes in winter and spring, and about 2.8 percent in summer and fall. The amount of spatial and temporal patterns of precipitation are changing (Watson *et al.*, 1998). These changes are responsible for bringing adverse consequences to human populations.

Environmental change and ecosystem degradation in particular are the result of many different occurrences in natural and/or man-made systems. Major parameters responsible for changes in ecosystems that affect human populations can be a result of direct manipulation or an environmental consequence of human activity.

Some direct cultural changes include:

- **Development and intensification of agriculture**

  The direct result of agricultural practices is the conversion of forest, grassland, and wetland ecosystems into agroecosystems, which are poorer in biodiversity and consequently less stable and resistant to other interventions. Other effects include soil and water contamination with chemicals and pesticides, land degradation, and salinization. (WRI, 1998).

- **Industrialization, increasing energy use, and urbanization**

  Industrial development and excessive energy use lead to direct changes and very often destroy ecosystems by simply occupying the space and converting natural environments into industrial sites and urban areas. Habitat fragmentation and loss in biodiversity, alteration and destruction of vegetation cover, removal and disproportional distribution of species, water (fish kills and eutrophication), soil degradation, and pollution contribute to changes in the global ecosystem. Stratospheric ozone depletion is also considered to be the result of industrial development (WRI, 1998).

Some environmental consequences of human activity include:

- **Changes in climate**

  According to the Intergovernmental Panel on Climate Change (IPCC) the mean surface temperature of the Earth may increase by approximately 1-3.5˚ C. Sea level rise due to climate change may lead to an increase in coastal zone erosion and loss of natural protective features such as dunes and mangroves. Potential health impacts are considered to be cumulative and interact synergistically (WHO, 1996).

  Changes in climatic conditions are enabling mosquitoes and other disease carrying insects to survive and breed more at northern latitudes and higher altitudes. The distribution of species in an ecosystem may vary due to such changes (Fig. 1).

- **Natural Disasters**

  Natural disasters may lead to devastating consequences to both natural and man-managed ecosystems. High amounts of rain may cause inundation of a river flood plain and

lowlands as well as degrade top soil layers and wash out nutrients and microelements. Volcanic eruptions can lead to ecosystems collapsing by polluting the atmoshpere and covering the land surface with lava and ash. Earthquakes may lead to land degradation and landslides that affect day to day life and loss of property, and droughts may lead to the loss of biodiversity and species migration.

Other activities, such as construction, forestry, hunting, fishing, and recreation, may lead to the loss of biodiversity, habitat fragmentation, river or stream regime alteration, resource extraction, vegetation cover destruction, disproportional distribution of species, and pollution of the environments.

The loss of species and habitat degradation erode genetic diversity. In addition, many of the 20,000 plant species used as traditional medicines around the world are under threat due to over-exploitation (UNEP, 1993). The genetic diversity of species is not only one of the keys to successful agriculture, which prevents malnutrition-related health problems, but also a source of pharmaceuticals and a field for medical research and findings.

The consequences of ecosystem collapse are often a breakdown in terms of biological, physical, social, and economic dimensions (Rapport *et al.*, 1998). Discovering original and improved ways to assess ill-health and problems in ecosystems, which represent the basic functional unit of the natural environment, is the emerging goals of the environmental-health interface.

The concept of the ecosystem distress syndrome is a syndrome that includes such ecosystem disturbances as changes in biotic composition and energy flow, loss of biodiversity and nutrient capital and, in general, the loss of the balance between ecosystem components. Acidified lakes, highly polluted coastal marine systems and estuaries, overgrazed grasslands, loss of valuable fisheries, desertification as a result of overgrazing, and invasions of exotic species are examples of ecosystem distress syndrome. These can influence human population health and may be readily detected, even by the general public, in all countries (Rapport *et al*. 1998).

3. HUMAN HEALTH

The World Health Organization (WHO) characterizes health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (Purdom, 1980). The major current trends of human health globally include the following features (WHO, 1996):

- increases in life expectancy,
- a decline in infant and child mortality in developing countries,
- reduction of certain vaccine-preventable diseases, and
- increased incidences of chronic non-infectious diseases and HIV/AIDS.

Still, avoidable illnesses and premature deaths are occurring in large numbers in many regions of the world, where environmental factors are responsible (NEHA, 1998). The sustainability of human health is a highly important criterion of successful social and economic policies.

The status of human health is a reflection of a whole variety of complex interactions between the internal biological and the total external environmental system. Health effects of one particular change in the environment should be assessed within the context of other coexisting environmental effects and occurrences, such as rapid urbanization, human population density and increasing mobility, increasing movement of

produce, resource exhaustion, desertification, and pollution. However, certain population groups, either because of their life-style, occupation, location or consumption patterns, are differentially vulnerable to specific health risks and threats. This, in combination with differential hazard exposure, may put the group at increased risk (Gopalan and Saksena, 1999).

As a possible result of environmental change during the past 20 years, about 30 new diseases (e.g., legionella, HIV/AIDS, ebola, hantavirus pulmonary syndrome, a new strain of cholera, and a host of antibiotic-resistant pathogens) have emerged (Gopalan and Saksena, 1998). Emerging diseases can be defined as infections that have newly appeared in the population or have existed and are rapidly increasing geographically. Environmental changes have contributed directly or indirectly in the growth of such diseases. Human activity, resulting in the ecosystem degradation and changes in human behavior favor the spread of the disease (Gopalan and Saksena, 1999).

4. IMPACT OF ECOSYSTEM DEGRADATION ON HUMAN HEALTH

The impoverishment of human health due to the degradation of the ecosystems may be described as an "illness resulting from disrupted internal balances due to external stresses" (Odum, 1995). It is becoming obvious that degradation of ecosystems is increasingly the root cause of many of the sufferings within the human community (Rapport, 1998). Ecosystems that are sufficiently stable and biologically diverse tend to maintain the quality of human health. Degraded or collapsed ecosystems — aquatic and terrestrial environments — seem to have a significant impact on human health.

An analysis of the literature on environmental health shows that there are many attempts to connect human health and the changing environmental conditions. One of the first and most significant contributions is the book, *The Silent Spring*, written by Rachel Carson (1966). She brought a new awareness to public attention that nature was vulnerable to human interventions. The threats to human health that Carson has outlined — the contamination of the food chain, cancer, and genetic damage — are found to be to important to ignore.

Another important contribution to the literature on environmental health has been made by a joint publication of the World Resources Institute (WRI), the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP), and the World Bank (WB) (WRI, 1998). This report clearly explains the multiple causes of environmental change and demonstrates the dependence of humans on the natural environment, taking into consideration social, economic and cultural variables. A number of UNEP reports and publications addressing the environmental health issues provide an excellent source of information on ecosystem degradation due to the unsustainable development, emphasizing the importance of maintaining the health of ecosystems in order to sustain and improve the status of human health.

Research articles and reports on different tropical emerging and re-emerging diseases (e.g. the Rift Valley fever in Kenya) try to link the changes in the environment and health showing the naturally occurring causes of the disease based on seasonal climate conditions changes (Linthicum *et al.*, 1999).

The inter-dependence of the state of the environment and the status of human health is complex and multi-disciplinary (Schirding, 1997). Development, environment, and human health concerns require an integrated approach. Indices of the sustainability of health status may be focused on the integrity and stability of the global ecological

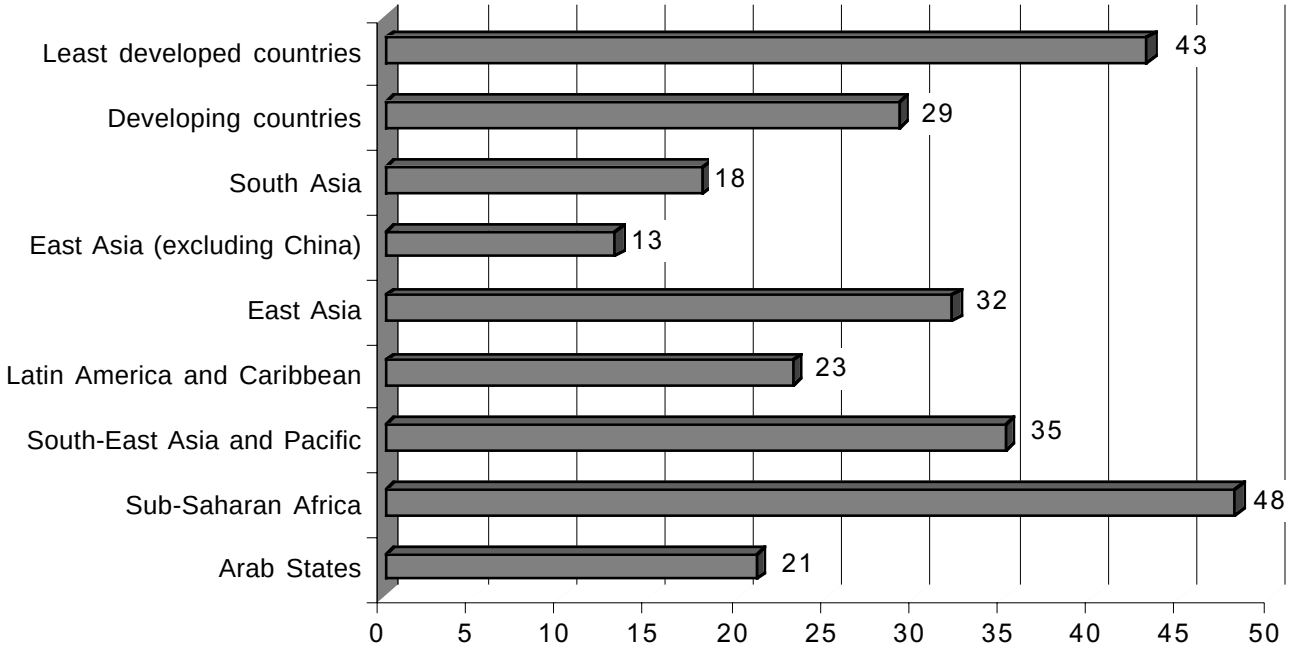

Figure 2. People without access to safe water - A regional profile 1990-1996 (percent).

(Source UNDP, 1998)

systems that maintain the life and health of the population. These indices may not directly measure human biology but may assess the degree to which human biophysical needs are being satisfied by the sustainable use of ecosystem services. The indicators may include bio-indices predictive of human disease risk, such as the degree of the balance between population size and available resources, or vegetation cover and groundwater levels in relation to infectious disease transmission (McMichael, 1997). Table 1 demonstrates basic data on the linkages between ecosystems, impact on human health, regional/local examples and consequences and/or possible occurrences of the threat and risk to human health.

The key research issue today is the fundamental infrastructural significance to human health of the biosphere's natural systems. The potential threats and risks from the global environmental change differ from well-recognized, locally found environmental risks to health from directly acting harmful agents. Disruption of natural ecological systems endangers the health of the population by a variety of direct and indirect ways, immediate and delayed mechanisms (McMichael, 1997).

Changes in the distribution and ecological activity of organisms, often resulting from environmental modifications, may give early evidence of environment-related shifts in human health risks. In many cases, disease appearances are symptoms of ecosystem dysfunction. They can also be considered as first recognized impacts of an environmental stress (WHO, 1996). There are some fundamental mechanisms and forms of ecosystem degradation that affect human health. According to Karr (1997), there are three major multi-dimensional mechanisms of environmental and human systems alteration:

- Indirect depletion of ecological systems (soil degradation, water supplies degradation, biogeochemical cycles alterations, climate change, ozone layer depletion, and water, air and soil pollution);

Table 1. Ecosystem Degradation and Human Health Consequences at a Regional/Local Level

Atmosphere					
Ecosystem	*Driving Forces*	*Changing Ecological Pattern*	*Regional/Local Example*	*Influence on Human Health*	*Additional Possible Consequences*
Climate	***Climate change*** Extremes in temperature: excessive heat [1]	Increased rainfall, frequency and severity of droughts	Rwanda, Ethiopia, East African highlands, Madagascar	Malaria	Further global mean temperature increase may create ecological conditions conducive to malaria in 60% of the world's land area, compared with current 45%; similar outcomes are possible with schistosomiasis
	Changes in temperature and humidity[2]	Extension of drought areas	Benin, Burkina Faso, Chad, Mali, Niger, Nigeria, Senegal, Togo, Ethiopia, Sudan, Rwanda, Tanzania, Uganda, Zambia	Meningococcal, disease epidemics	Aggravated by increased mobility of people
	Natural disaster Droughts[ii]	Deficiency in micronutrients	Northeast Africa	Starvation, malnutrition, related diseases	Health consequences may include diseases from a breakdown in sanitation
	Global climate change Extremes in temperature: excessive heat[ii]	Development of favorable conditions for dissemination of arboviruses	Australia, Oceania	Dengue, arboviral infections	
	High temperatures Extremes in temperature: excessive heat[ii]	Summer climate is becoming warmer	Guangzhou and Shanghai, China	Excess in the rate of heat-related deaths in summer	Sporadic heat waves would continue to occur rendering population acclimatization less likely
	Climate change Extremes in temperature[ii]	Excessive heat	USA	Excess in the rate of heat-related deaths in summer, physiological disturbance	The elderly, the very young, people with impaired mobility, and those suffering from cardiovascular disease are more affected
	High precipitation period following a period of drought	Increase in population of deer mice	Southwestern USA	Hantavirus	
	High temperatures Extremes in temperature[ii]	Increase the length of the period of mosquito development	Mexico	Dengue infection	

Table 1. Ecosystem Degradation and Human Health Consequences at a Regional/Local Level

Ecosystem	Driving Forces	Changing Ecological Pattern	Regional/Local Example	Influence on Human Health	Additional Possible Consequences
Atmosphere					
	Global climate change Variations in temperature, precipitation, and humidity[ii]	Changed behavior and geographical dispersion of vector organisms; savannas may become sub-tropical, western parts may become warmer and drier	Argentina	Malaria	In human-made ecosystems vector species have better adapted
Pollution	***Pollution*** from power plants, metallurgy, the coal industry, the chemical industry, and vehicular emissions	Lower visibility	A large number of countries	Respiratory diseases are the fourth leading cause of death	
	Radioactive contamination[3]	Accumulation of radioactive elements in different parts of ecosystem	Ukraine, FSU	Birth defects, mental anomalies, immune disorders	Full health effects cannot be known immediately
Aquatic Ecosystems					
Ecosystem	*Driving Forces*	*Changing Ecological Pattern*	*Regional/Local Example*	*Influence on Human Health*	*Additional Possible Consequences*
Marine	***Biological contamination*** Water contamination with waste water[4]		South Africa	Gastroenteritis, eye and skin infections	
	Pollution Oil contamination Industrial pollution and pollution from naval operations and sewage discharges[i]	Deterioration of marine ecosystems from a severe imbalance due to severe navigation	Black/Azov seas Caspian Sea	Decrease in life expectancy, skin and eye diseases	Marine species are severely affected
	Biological/bacterial contamination due to hydrological changes[5]	Fish and algae effects	Central Asia	Typhoid, malaria, diphtheria	
	Rising levels Ecosystem destruction and pasture degrad-ation; decrease in depth and amplitude of water fluctuations lead to reduction of wildlife habitats[i]	Further rising may bring hydrogen sulfide and petroleum products pollution to the Volga River	Caspian Sea	Skin, eye diseases	

Table 1. Ecosystem Degradation and Human Health Consequences at a Regional/Local Level

Aquatic Ecosystems

Ecosystem	*Driving Forces*	*Changing Ecological Pattern*	*Regional/Local Example*	*Influence on Human Health*	*Additional Possible Consequences*
	Biological contamination Water contamination with waste water[iv]	United Kingdom, France	Gastroenteritis, eye and skin infections		
	Biological and chemical contamination Harmful (toxic and nontoxic) algal blooms from the rapid reproduction and localized dominance of phytoplankton[iv]	Shellfish poisoning, wildlife mortalities, sunlight penetration prevention, oxygen shortages, reservoirs for bacteria	Northeast Florida, Gulf States, coastal regions of South America	Poisonings, diarrhea, dehydration, headaches, confusion, dizziness, memory loss, weakness, gastroenteritis, bacterial infections, swimming related illnesses, neurological diseases, deaths	Many outbreaks accompany El Nino events
	Contamination Cholera contaminated sea plankton due to contaminated ships' hulls[iv]	Coastal shellfish and fish contamination	Peru and 16 other countries	Cholera	The situation is aggravated by poor sanitary conditions
Freshwater	***Dam Construction*** Hydro-geological cycle changes[i]	Inundating of lands	Senegal River: Manantali and Diama Dams	Epidemic of schistosomiasis	Infection rates in the Diama region went from zero before the dams to more than 90% of the population.
	Changes in Hydro-geological cycle[6]	Inundating of lands	Yangtze River, China	Intestinal nematode infections	Possibility of promotion the emergence and reemergence of new helminths and their snail vectors
	Changes in water flow[7]	Habitat alteration, new breeding sites for mosquitos	Senegal	Rift Valley fever	
	Scarcity and Degradation of Water Resources Contaminated river systems[i]	High levels of suspended soils and fecal bacterial content	South Africa	Fecal infections, intestinal diseases	Inadequate sanitation
	Pollution Pesticides, herbicides, mineral fertilizers, and defoliants contamination. Airborne toxic salts[i]	Water quality deterioration	Central Asia	Health problems (general) and infant mortality and morbidity	

Table 1. Ecosystem Degradation and Human Health Consequences at a Regional/Local Level

Ecosystem	Driving Forces	Changing Ecological Pattern	Regional/Local Example	Influence on Human Health	Additional Possible Consequences
Aquatic Ecosystems					
	Pollution Water contamination with heavy metals (Cadmium)	Accumulation in biochains	Japan	Progressive and irreversible kidney damage	Damage continues even after the exposure is ceased
	Fecal water pollution[i]		Bangladesh, India	Diarrhea Hepatitis	Frequent occurrence during monsoons and floods
	Declines in ground water levels Groundwater contamination	Declines have been implicated in the wide-spread arsenic contamin-ation of well water	Bangladesh, India	Poisoning	Effects not often seen until damage has occurred
	Degradation Fallen water tables Chemical contamination[8]	Severe increase in salinity	Gazan aquifer, Palestine, Israel	Cholera outbreak (1995), infectious diseases, intestinal parasites	23% of Gaza's water is not drinkable; groundwater is contaminated with chlorides, potassium, nitrates, and fluorides
Terrestrial Ecosystems					
Ecosystem	*Driving Forces*	*Changing Ecological Pattern*	*Regional/Local Example*	*Influence on Human Health*	*Additional Possible Consequences*
Vegetation	**Deforestation** Soils destab-ilization	Changes in local hydrological cycles	South Africa	Malaria	Decreased efficiency and increased ill-health; Increase air pollution;
	Deforestation[vi]	Firewood shortage, land degradation	Gambia, Kenya, South Africa, Zimbabwe	Firewood collection, transportation, processing cause; Trauma, allergic reactions, aches, cuts, infections, respiratory diseases, cancer	Dependence on other sources of fuel Most cases occur among young male adults; Sociocultural peculiarities complicate the situation
	Clearing and intervening the forests[vi]	New breeding grounds for insects	Ghana, Nigeria, Zaire, Sudan, Liberia, Cote d'Ivoire	Yellow fever	Decreased efficiency and increased ill-health; Increased air pollution; Dependence of other sources of fuel

Table 1. Ecosystem Degradation and Human Health Consequences at a Regional/Local Level

Terrestrial Ecosystems					
Ecosystem	*Driving Forces*	*Changing Ecological Pattern*	*Regional/Local Example*	*Influence on Human Health*	*Additional Possible Consequences*
	Deforestation[vi]	Firewood shortage, land degradation	Nepal, China, India	Ebola epidemics (possible connection) processing cause; trauma, allergic reactions, aches, cuts, infections, respiratory diseases, cancer	Increased air pollution; dependence on other sources of fuel Most cases occur among young male adults
	Clearing of forests[vi]	New breeding ground for insects	Peru, Bolivia, Brazil	Yellow Fever	
	Conversion of forest into cotton and sugarcane culture, and cattle pasture[vi]	Land use changes leading to favorable habitats for rats which are the sources of infection	Venezuela	Hemorrhagic fever	Displacement of population
		Alteration of hydrological cycles	Honduras	Malaria	
	Natural disaster Forest and rangeland fires due to high temperature, strong winds and low soil moisture content [ii]	Affect ground-level and/ or crown vegetation and result in extremely high temperatures	Australia, USA	Burns, smoke inhalation	Loss of vegetation on slopes leads to landslides, which is dangerous for urban areas at most
	Agroecosystem development: inundating of lands due to rice growing	New breeding grounds for insects	Japan, China, India	Japanese encephalitis	Rare in other parts of the world
	Intensified agriculture Irrigation schemes damaging local ecosystems	Insecticide resistance	Central America	Malaria	
Land Degradation	***Changed agricultural patterns*** Destruction of the agricultural ecosystem[ii]	Increased availability of breeding sites for insects	East African highlands and Madagascar	Malaria	Aggravated by increased temperatures

Table 1. Ecosystem Degradation and Human Health Consequences at a Regional/Local Level

Terrestrial Ecosystems					
Ecosystem	*Driving Forces*	*Changing Ecological Pattern*	*Regional/Local Example*	*Influence on Human Health*	*Additional Possible Consequences*
	Desertification Shrub and tree cover reduction[10]	Drying of climate	Different types of parasites in different parts of the continent	Human African trypanosomiasis (sleeping sickness)	Land use changes and humidity variations affect the survival of vector species
	Radioactive contamination Soils contamination[i]	Food grown is very contaminated	In Siberian and Arctic regions, ecosystems are the most vulnerable	Raising incidence of cancer, birth defects	
	Soil contamination Fertilizers and organic manure contamination[vi]	Increase in nitrate level leading to the high levels of nutrients in rivers	Western Europe	Bottle fed babies are at serious risk	Possibility of carcinogenesis
	Land conversion Transformation of agricultural ecosystems[11]	Displacement of deer and their ticks and foster the geographic spread of the enzootic foci	USA	Lyme disease	
	Land transformation Mining activities leading to land degradation[12]	Accumulation of mining dust	USA	Lung diseases	Possibility of carcinogenesis
	Mining activities leading to land degradation, deforestation[ix]		Brazil	Exposure to mercury	Population migration
	Soil qualities impairment Contamination with pesticides[ix]	Accumulation in food chain	Moldova, FSU	Infections of respiratory and digestive tracts	Immune system suppression

[i] Chen *et al*.,1997 [ii] WHO, 1996 [iii] Feshbach and Friendly, 1992 [iv] HEED, 1999 [v] UNEP, 1999 [vi] Gopalan and Saksena, 1999 [vii] WRI, 1996 [viii] Homer-Dixon and Percival, 1996 [ix] WRI, 1998 [x] McMichael, 1996 [xi] PAHO, 1999 [xii] NIEHS, 1999

- Direct depletion of non-human living systems (loss of biodiversity, renewable resources exhaustion, pest outbreaks, spread of alien species); and
- Direct depletion of human systems (epidemics, emerging and re-emerging diseases, and reduced quality of life).

4.1 Aquatic Ecosystems

Water pollution continues to degrade both freshwater and marine ecosystems, which in turn causes difficulty in obtaining safe drinking water (Fig. 2). Water related diseases causes millions of preventable deaths every year, especially among children (UNDP, 1998). Table 2 shows classifications of water related diseases.

Greater incidence of illness due to consumption of contaminated fish and shellfish is an increasing concern. Harmful algal blooms in many coastal regions in the world cause a number of diseases, including poisoning, neurological disorders, and gastroenteritis (HEED, 1999; UNEP, 1999). Increased flooding as a result of changes in precipitation may cause contamination of water supplies, which leads to greater incidence of fecal-oral contamination (WHO, 1996). Also, eutrophication — a process of water quality degradation caused by excessive nutrients — is depriving lakeside residents of good water quality in many densely populated areas of the world (UNEP, 1994).

4.2 Terrestrial Ecosystems

Expanding agriculture, deforestation, mining activity, dam building, irrigation schemes, and unplanned urban development are activities which change the structure and functioning of terrestrial, as well as, aquatic ecosystems. These activities pose a number of health concerns, such as increased exposure to toxic substances and increased exposure to infectious agents because mosquitoes would be provided with new breeding grounds, (Gopalan and Saksena, 1999).

Deforestation and hunting bring people into contact with animals which can lead to transmission of various diseases, including the simian virus closely related to HIV which are found in African chimpanzees. These animals' disease-fighting immune mechanisms are able to control the virus and by studying these mechanisms scientists may obtain important clues as how to prevent and treat

Table 2. Classification of water related diseases.

Category	Examples
Waterborne: microbial and chemical	Typhoid, cholera, fluorosis
Water-washed: skin and eye, diarrhoeal diseases	Scabies, trachoma, bacillary dysentery
Water-based: penetrating skin, ingested	Schistosomiasis, guinea worm
Insect vector related diseases: vector bite, breeding in water	Sleeping sickness, yellow fever

(After Gopalan and Saksena, 1999)

the devastating infection in people (Waldholz, 1999). Ebola hemorrhagic fever may also serve as an example of a possibly animal-borne disease, however, the exact origin, location, and natural habitat of the virus remain unknown (CDC, 1999). An association between forest fragmentation and ebola cases is still unclear. Deforestation may continue at high rates until most of us see the value of forests for biodiversity, potential medicines, improved environmental quality, and climate mitigation (NIEHS, 1999).

In areas where forest cover is interrupted, nutrients are released into the hydrological cycle. A net nutrient outflow pollutes local river systems and greatly reduces the productive capacity of the cleared land (WCMC, 1992). According to the National Institute of Environmental Health Sciences (USA), deforestation changes natural habitats and creates several human health concerns such as an increase in infectious diseases, depression, and alcohol abuse. These can result from deforestation and the disruption of habitats and cultures.

In Southeast Asia, deliberately set fires have increased pollutants in the atmosphere that cause respiratory problems and contribute to global climate change. Forest fires have a profound impact on the physical environment including: land cover, biodiversity, climate change and forest ecosystems. Health impact is often serious. Estimates suggest that 20 million people are in danger of respiratory problems from fires in Southeast Asia. Large fires also occurred in the Caribbean region, Africa and some parts of the Former Soviet Union (Levine *et al.*, 1999).

4.3 Global Climate Change

Temperature and weather changes through different mediating processes may have direct and indirect health outcomes. Exposure to thermal extremes and altered frequency of weather events may result in altered rates of heat- and cold-related illnesses, psychological disorders, and deaths. Indirect results often affect the range and activities of vectors, alter food productivity, sea level rise, increase air pollution, and others may lead to increases in diarrhoeal and vector-borne diseases, malnutrition, impairment of child growth and development, asthma, allergic and respiratory disorders, and deaths (WHO, 1996).

Almost all climate scientists accept the notion that the likely increase in, and spread of, many diseases are likely to be the single most dangerous threat that climate change poses to human health (Kingsnorth, 1999). Global climate change may create favorable conditions for disease carrying insects to proliferate at more northern latitudes and higher altitudes. Malaria, dengue, yellow fever and some other types of viral encephalitis are likely to increase. According to the World Health Report (WHO, 1996), approximately half of the world's population are at risk of insect-borne diseases. Malaria provides an important example, because it presently accounts for approximately 350 million cases annually, including about 2 million deaths (McMichael, 1997). The impact of extreme weather events on human health includes death, injuries, stress-related disorders and the many adverse health effects associated with the social disruption and enforced migration. Increased frequency of extreme weather events could also have indirect impacts on population health, including greater incidence of infectious diseases, mainly due to factors such as failure in sanitation and lack of clean fresh water (Fig. 3).

Significant stratospheric ozone losses have occurred mainly at middle and high latitudes. Ozone depletion is more pronounced during winter and spring seasons compared to a summer season. An increase in ultraviolet exposure may increase the incidence of skin cancers, the severity of sunburn,

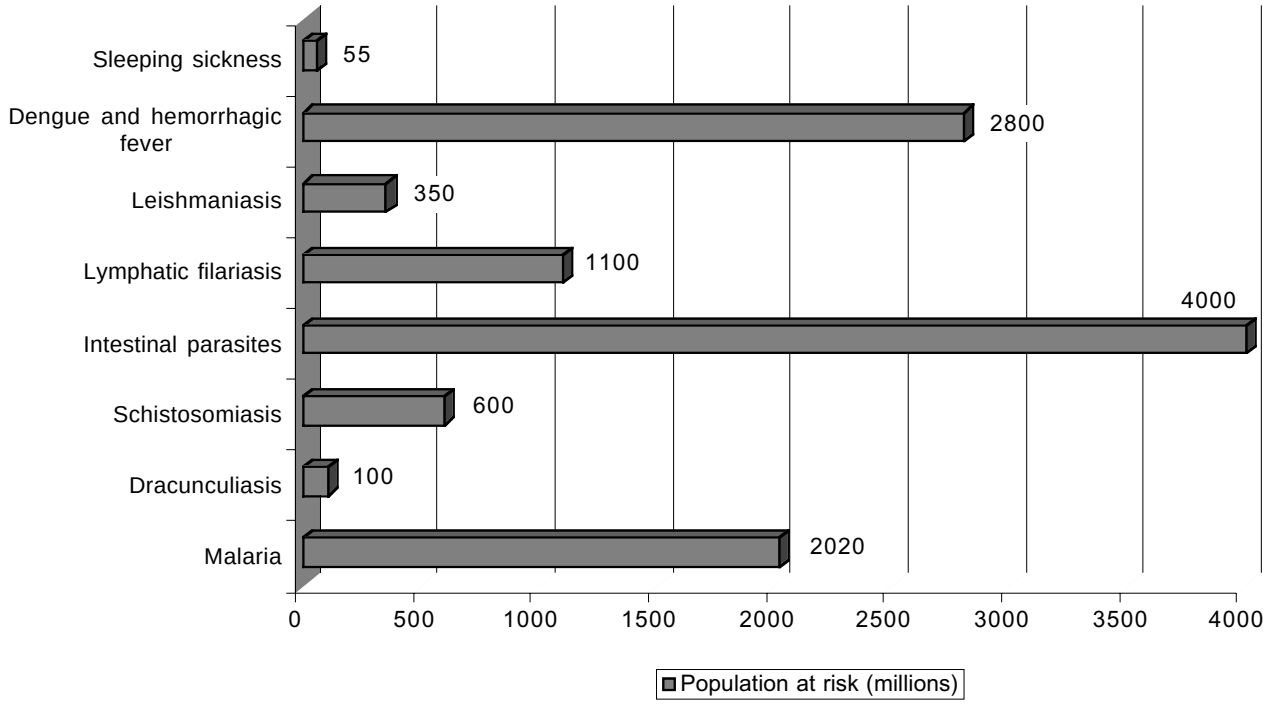

Figure 3. Estimates of population risk due to water related diseases.

(after Gopalan and Saksena, 1999)

skin aging, and eye diseases (cataracts). The negative effects of ozone layer depletion may also include some suppression of immune functioning, thus increasing the susceptibility to infectious diseases (McMichael, 1997).

The extent of environmental threats to human health is distributed unevenly in developed and developing countries. In some countries the effects of a degraded ecosystem or transformed environment is exacerbated by inadequate sanitation and nutrition, cultural differences, and demographic features. In areas where environmental threats coincide with poor social and economic conditions risks and threats to the population health are higher. In general, countries in Africa and parts of Asia seem to face the highest health threats from the degradation of ecosystems.

Many of the parameters associated with environmental change and patterns of disease can be monitored and mapped by airborne and satellite borne sensors, and modeled spatially with specialized computer software. Remote sensing technology and Geographic Information System (GIS) technologies can be used to describe local and landscape-level features that influence the patterns and prevalence of disease and their occurrence can be modeled in space and time (CHAART, 1999). However, the capabilities of remote sensing techniques have not been disseminated to the health investigators and agencies that could be using them. It goes without saying that surveillance, modeling and early warnings are the main goals of human health systems. However, the science needed to create such a system has not been completely done (Guptill, 1998). Good surveillance means that the factors being monitored, such as weather and vegetation cover, are well known and identified. In addition, the way of relating these components to demographic information to determine the population risk has to be established. The simplistic logical connections between weather patterns, vegetation, and disease

incidence usually lack scientific rigor (Guptill, 1998).

For most of the potential impacts of ecosystem degradation on human health, information upon which to build a standard health risk assessment seems to remain inadequate. Most of the research articles, books and reports, which attempt to connect the deterioration of the environment and its impact on human health, focus mainly on the social, economic and/or demographic consequences of such interactions rather than use of an ecosystem approach. Another problem with connecting the disease in humans and the ecosystem degradation is that in many publications these links are not clearly explored, as ecological and medical issues are discussed quite separately with an emphasis on either of these issues.

Literature review shows that there is a continued trend in environmental health publications to connect the physical degradation of the Earth with the quality of human health, but links are mostly established through social, economic and legal spheres, such as infirmities in health care, pollution abatement measures, and poor sanitation. The slow growth in world food output contributes to a reversal in economic progress in many countries and chemical contamination of agricultural production are being constantly mentioned. In addition, many conclusions are drawn on the inference that the ties between environmental abuse and population health remain inevitably more presumptive than proven (Feshbach and Friendly, 1992). Air and water pollution and climate change remain the main spheres from which the discussion of the human health problems in connection to the ecosystem degradation starts and develops.

Many sources on the subject provide numerical data on levels of pollution, health status examples, or medical statistical data, leaving readers with the opportunity to make their own conclusions. Moreover, traditional environmental health risk assessment is based on 1) identifying a discrete health threat, 2) characterizing the resulting health risk, 3) evaluating possible human exposure, and 4) concluding by estimating likely disease outcomes. Such approaches seem to be inappropriate if the health risk is connected to an ecological entity or ecosystem phenomenon, such as weather events, quality and quantity of water resources, vegetation cover and others (WHO, 1996). Even if the concept of an ecosystem is rather broad, taking into account the fact that an ecosystem is a functioning unit of the environment and can be represented by both a small lake and a watershed, some sources tend to consider separate parts of ecosystems.

The significant aspect of human action and their total impact on ecosystems rise from specific pollutants, but recognition of this overall effect is necessary for identifying the real problem of ecosystem degradation. A total reflection of the environmental impact on man should also consider psychological influences and hazards, even though their precise effects, the magnitude of their influence or the epidemiology of mental illnesses are not well-known (Purdom, 1980).

Environmental health studies are not well developed for analysis of ill-health causes involving a combination of environmental factors that interact with one another and are themselves components of complex systems affected by human interventions. Empirical sciences experience difficulties in dealing with the uncertainties arising from such complex systems and their predictive modeling. Adequate consideration of the health impact of ecosystem degradation on human society, and of societal efforts to mitigate or adapt to such changes, necessitate multi-disciplinary research that draws heavily on the environmental health sciences, epidemiology, anthropology, social psychology and others (WHO, 1996). According to McMichael (1997), better understanding, assessment, and dealing with the

problem of the impact of transformed ecosystems on human health requires the attention of the global community on:

- Practical research into the health impacts of environmental modifications
- •. Environmental modeling for the prediction of the population health outcomes.
- Prediction, forecasting and estimating of possible future scenarios

There is no lack of warnings, pronouncements, and declarations on the issue of the human health in connection to the degraded ecosystem from scientists, politicians, humanists, business society, and interested agencies (Rapport, 1998). Reports and other publications of UNEP, WRI, WHO, and other organizations provide the necessary material on the environmental health subject. The problem is how this information is presented, where the emphasis is placed, and how and to whom the information is disseminated and used. A proper understanding of the threats from the degraded ecosystem to human health is necessary. The strengthening of collaborative agreements between agencies may help to enhance scientific quality and extend data resources (DHHS, 1984).

4.4 International Workshop on "An Ecosystem Approach to Human Health: Communicable and Emerging Diseases."

Recently, an international workshop, "An Ecosystem Approach to Human Health: Communicable and Emerging Diseases" (November 8-12, 1999) was held in Rio de Janeiro, Brazil. The meeting was sponsored by the International Development Research Centre (IDRC-Canada), UNEP, the Pan American Health Organization (PAHO) in Brazil, and the National School of Public Health of the Oswaldo Cruz Foundation (ENSP-FIOCRUZ), which hosted the event.

The multiple associations between the disruption of agro- and urban ecosystems throughout the Americas and increased occurrences in tropical diseases such as malaria, dengue, chagas, and leishmaniasis were discussed and analyzed. The group examined social, demographic, and ecological dimensions at various scales, and the implications for ecosystem health of development projects. Significant attention was made to studies that analyzed the inter-relationships between ecosystem disruption and emerging and re-emerging diseases. The workshop produced integrated policy options for prevention of emerging diseases and maintaining good human health.

Participants included seventy researchers and scholars from different countries of Latin America, North America, and Africa. They discussed the implications of using an ecosystem approach to understand and prevent communicable diseases. They also called for stronger institutional links to develop, disseminate, and implement an ecosystem approach to human health. The participants stressed an urgent need for collaborative efforts to support and maintain inter-disciplinary research, as well as participatory and inter-sectional strategies to encourage an improved management of stressed ecosystems. Specific ecosystem methodologies were proposed to deal with the expansion of several tropical and emerging diseases in developing countries. The ecosystem approach was agreed to be central to our ability to move beyond the management of specific diseases and to promote sustainable human health.

4.5 Canadian Conference on International Health

The 6th Canadian Conference on International Health (CCIH) took place in Ottawa/Hull, Canada in November, 1999. The conference was organized by the Canadian Society for International Health

Figure 4. Mutually tied changes in ecosystem and human health.

(CSIH) with technical representatives in Canada for the Pan American Health Organization (PAHO) and the World Health Organization (WHO). Sponsors of the conference were PAHO, International Development Research Center (IDRC), and UNEP. IDRC and UNEP were interested in the relationship between ecosystem disruption and human health consultation.

During the CCHI, participants considered aspects of the overall challenge of integrating natural resource, economic, social, and health sciences for the purpose of seeking ways by which natural resource management can be used to foster improved human health. The presentations addressed important crosscutting issues such as system complexity, social and gender analyses, globalization and participatory methods as well as specific issues relevant to agricultural, urban, and coastal systems. Ecosystem processes that affect human health and the feedback of human on their capacity to undertake sustainable use of natural resources were discussed. Culturally, professionally, and geographically diverse participants reflected on the issues concerning food security, equity in natural resources use, biodiversity conservation, sustainable employment, strategies and policies for healthy societies, and information and communication.

To conclude the conference, a forum was held where practitioners decided upon new trans-disciplinary concepts for research and development on interventions that could maintain and improve human health in degraded and disrupted ecosystems. Practical ways were delineated in which institutional arrangements could be created to foster research and development in ecosystem management interventions to improve human health.

5. CONCLUSIONS

The potential impact on human health due to the degradation of the ecosystem is an outcome of several simultaneous processes such as deforestation, pollution, global climate change, and very often mutually-tied changes (Fig. 4).

A basic obstacle to the assessment of the human health status in relation to ecosystem degradation and establishment of direct links between ecosystem collapse and human disease lies in coping with absence of direct, strong, connective mechanisms, and scientific uncertainty. Ozone layer depletion, loss in biodiversity, and pesticide accumulation affecting human health is based on the understanding that the influence is going through the energy and food chain, often through various indirect pathways. There always seems to be intermediaries connecting the change in the ecosystem and human health. For example, such environmental changes as climate change, land degradation, and aquifer depletion seriously affect agricultural production. Agricultural production is a major determinant of nutritional status and population health. Hence, human health is affected by producing or consuming agricultural production and not directly by land degradation or aquifer depletion. However, there are some environmental changes that directly affect the quality

of human health, such as a rise in temperature, which causes thermal stresses, respiratory problems, and deterioration of aquatic ecosystems leading to waterborne diseases. Other health impacts of the ecosystem degradation may be exasperated by changes in other systems and processes, such as proliferation of bacteria, distribution of vector organisms, or quality and availability of water supplies.

The significant changes in health conditions are posing a demand for knowledge and are calling for new solutions in implementation of environmental health policies. Government agencies which are responsible for health assessment, policy-making, regulations, and health quality assurance require an ongoing production, collection, and analysis of information about the impacts of the changed ecosystems on population health (PAHO, 1999). Public health programs can help reduce the health impacts caused by ecosystem degradation. Surveillance systems could be improved or installed in sensitive geographic areas. Inter-disciplinary collaboration should be enhanced so that public health considerations are incorporated into the development process.

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7. Acronyms Used

CCHI	Canadian Conference on International Health
CDC	Center for Disease Control
CHAART	Center for Health Applications of Aerospace Related Technologies
CSHI	Canadian Society for International Health
DEIA & EW	Division of Environmental Information, Assessment & Early Warning
DHHS	Department of Health and Human Services
ENSP-FIOCRUZ	National School of Public Health of the Oswaldo Cruz Foundation
GIS	Geographic Information Systems
HEED	Health Ecological and Economic Dimensions
IDRC	International Development Research Center
IPCC	Intergovernmental Panel on Climate Change
NASA	National Aeronautics Space Administration
NIEHS	National Institute of Environmental Health Sciences
PAHO	Pan American Health Organization
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USGS	United States Geological Survey
WB	World Bank
WHO	World Health Organization
WRI	World Resources Institute