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THE EARTH SCIENCES, HUMAN WELL-BEING AND THE REDUCTION OF GLOBAL POVERTY

Poverty is not solely a social or political matter, nor is it caused simply by population pressures as Thomas Malthus postulated in 1798. A new understanding of poverty is emerging in which natural and environmental drivers, together with social, political, and demographic causes, underpin livelihoods. The Earth sciences, therefore, play a critical role in identifying the deep causes of human suffering and in identifying solutions.

The State of the Planet: Why Are So Many So Poor?

For far too many the state of human well-being is bleak. Around one in six human beings-l billion people-live in extreme poverty, struggling to survive on less than $1 a day; another one sixth of humanity ekes out existence on $2 per day [U.N. Development Programme (UNDP) Human Development Report, 2004; http://hdr.undp.orgi2004f]. The extreme poor lack all normal attributes of a decent, dignified life: adequate food, housing, sanitation, health care, education, and employment. Some 800 million people lack sufficient nourishment almost every day. It stunts their mental and physical development and shortens their lives, making them susceptible to common illnesses that attack their hunger-weakened bodies. Poor nutrition in mothers and infants is the leading cause of reduced disability-adjusted life years in poor countries (Economist, 2004).

Poverty worldwide claims 30,000 lives every day-one life lost about every 3 seconds-and in places like Sub-Saharan Africa, the situation worsens daily.

How can our world be this way? Population pressures, as Malthus described, surely make a difference. In areas of high rural population density, farm households tend to be extremely poor, and landless rural peasants are even poorer. Yet some places, like Japan, also have low land areas per person and are rich, while other places, like Bolivia, have large land areas per rural household and are extremely poor.

Governance and political institutions matter a lot, as seen in the striking differences between North and South Korea, but countries in extreme poverty lack the resources to combat basic causes of hunger and illness and cannot simply "govern" themselves out of poverty.

The root causes of poverty are complex, involving a suite of time-variable determinants, contingent influences, and internal feedbacks, many of which are location-specific. Economists and other social scientists have sought to understand the basic causes of, and solutions to, poverty (Landes, 1998), but the extent to which the condition of Earth's natural systems determines the state of the human condition has remained largely unanswered, and is only rarely incorporated into poverty studies. Studies by Jeffrey Sachs (Sachs et al. 1999; Sachs, 2005), who is the author's colleague and director of the Earth Institute at Columbia University, offer one exception, but even Sachs emphasizes how little of such research is currently under way in the economics profession.

Earth's Extremes and Human Well-Being

As seen from the tragedy of the Sumatra-Andaman tsunami of 26 December 2004, the poorest suffer disproportionately at the hands of nature. That tsunami followed the catastrophe in Haiti caused by storms in 2004. Beyond the immediate death toll, poor countries affected by disasters have the least capacity to recover, and few resources available for programs that stimulate long-term economic growth.

Whether reconstruction aid from outside comes as loans to be repaid, which diverts funds from development programs, or as a donation, productivity losses and the disruption of lives that follow major disasters can impede growth and even destabilize governments. A 2004 UNDP report (http://www.undp.org/bcpr/) details how disaster risk reduction could be a key in achieving the U.N.'s Millennium Development Goals (http://www.un.org/millenniumgoals/).

Figure 1 depicts a clear relationship between human development and mortality risk from natural hazards.

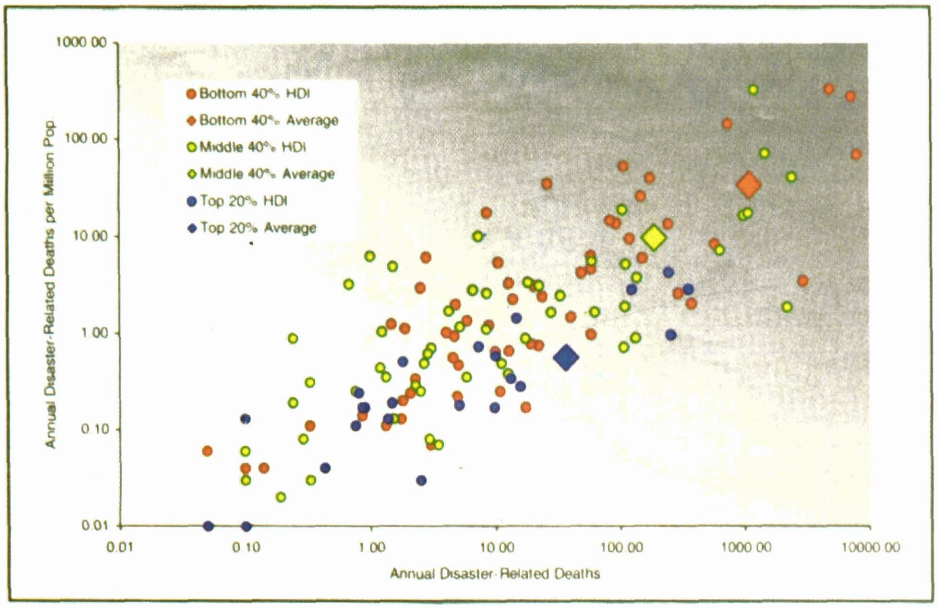

Fig.1. Average annual death toll for all hazards against the death toll relative to population, 1980-2000. Highly impacted countries are in the upper right where many deaths occur; and those deaths are in high proportion to population. Countries are colored with the Human Development Index (HDI) that combines indexes of per capital income with health status (longevity) plus a measure of educational opportunities. A simple average is included. While there is a great deal of spread indicating that a variety of influences are important, there is a clear relationship between human development and mortality risk from natural hazards.

The causes that underlie the relationship are numerous. The urban poor have little choice but to live in high-risk, "informal settlements" around major cities close to work opportunities-in riverbanks subject to flooding, on the slump scars of landslides on denuded slopes, or in crowded coastal regions such as those where so many died around the Indian Ocean from the recent tsunami.

In Haiti, rural poor denude the land of trees to raise crops at low yields and to produce charcoal to sell cheaply. Cleared land promotes flash flooding and the disasters that took about 6000 lives there in 2004 compared with about 100 in the U.S. Gulf Coast from the very same storms.

Earthquakes, too, exact the greatest toll on the poorest people. Zoback (2004) points out that the 1989 Loma Prieta earthquake in California (magnitude 6.9) left 63 dead and more than 3700 injured, while the 2001 Bhuj quake in Gujarat, India (magnitude 7.6), killed over 13,000 and injured more than 100,000.

Poverty and disaster vulnerability are codependent: while vulnerability is an outcome of poverty, it is a likely cause as well. A feedback develops that traps the poor into a spiral of increasing deprivation. Poor countries in the front line of natural hazards are more likely to get stuck in poverty, and parts of the world subject simultaneously to several hazards, notably Central America, the Andean countries, and parts of Southeast Asia, are particularly hard hit and the most likely it seems, to be trapped by hazards.

Variations Closer to the Norm

Cane et al.'s (1986) insight into the influence of El Nino-Southern Oscillation (ENSO) variations on grain production in Zimbabwe show a co-variance between sea surface temperature anomalies in the eastern equatorial Pacific and maize yield that has significance for large deviations from normal (El Nino years may bring drought and famine) and across much smaller variations. Similar relationships exist for agricultural production in northeastern Brazil, and fisheries off Peru.

Sub-Saharan Africa is home to about 90% of the world's malaria morbidity and mortality, the spatial and temporal dynamics of which relate to climate conditions. Underlying ecological conditions there have made the disease particularly difficult to control, much less to eliminate (Gilles, 1993; Gallup and Sachs, 2001). Extreme rainfall anomalies may lead to major epidemics (Brown et al. 1998), but ENSO-driven variations well within the range of normal conditions also have marked effects (Fig.2; M.C. Thomson et al., Climate monitoring for malaria early warning in Botswana, submitted to Emerging Infectious Diseases, 2004).

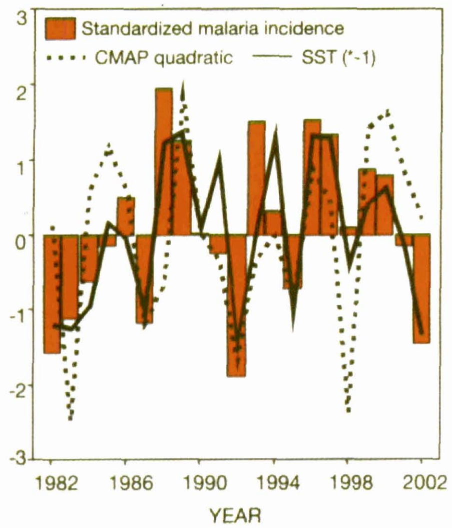

Fig.2. Malaria incidence anomalies in Botswana related to climate anomalies. Anomalies in sea surface temperatures (Nino 3.4), December-February (DJF), a quadratic rainfall model (measured using Climate Prediction Center Merged Analysis of Precipitation (CMAP)) for the same months are overlaid on standardized malaria cases per 1000 population (incidence) anomalies (for the period 1982-2003; main transmission period January-May). The malaria data have been standardized to remove non-climate-related trends and the impact of a major policy intervention in 1997. There are many factors that can cause changes in malaria incidence data, including changes in reporting, drug resistance, and control initiatives. However; in the semi-arid areas of Africa, rainfall is a major driving force of inter-annual variability in malaria. Where sea surface temperatures are significantly related to these changes, it may be possible for health services to use seasonal climate forecasts to predict malaria anomalies, before rains have fallen.

ENSO variations are a set of semi-periodic variations that dominate the climate signal in equatorial regions that are also host to the poorest in the world. Their susceptibility to these variations will amplify the consequences of relatively small changes into disasters.

Disease burden, like natural hazards, increases the resources needed for basic survival, diminishes opportunity for individuals, and encumbers scarce resources that could be used for economic growth (World Health Organization Commission on Macroeconomics and Health, 2001). Unhealthy people are less productive, cannot fully benefit from education to gain better jobs, and require more public expenditure (if available). Whether from a health or food security perspective, climate is indirectly, but certainly, an influence on human well-being.

Just as ENSO-driven climate variations imperil the livelihoods of the poorest and most vulnerable, global climate change, even by a small amount, puts poor societies under threat.

A Global Ecology of Poverty

The poorest often have few choices available to adapt to variations in natural conditions; they may not be able to harvest water, plant different crops, move to less stressed regions, or provide disaster-resilient infrastructures. Scarcity often means more time spent foraging for food and fuel. Haiti's deforestation is one example of a feedback loop in which attempts to cope with poverty themselves amplify the conditions that produce further poverty (Mutter, 2004).

Countries caught in or near this feedback amplification have a suite of characteristics that Sachs et al. (2004) identify as an ecology of the human condition. They point out that most of the world's poorest people live in tropical or arid countries, due neither to historic accident nor the fault of government (Figure 3a). These people are vulnerable to tropical climate extremes, diseases, pests, soil nutrient depletion, land degradation, and, in some regions (mountainous sites of high population density and the interior of sub-Saharan Africa), very high transport costs of needed goods and products to market.

Vulnerability to natural variations in Earth's behavior preferentially affects the lives of the poorest concentrated in equatorial regions (Figure 3), and suggests that Earth's natural processes contribute to an ecology of poverty. Many consequences of ENSO, for instance, have their greatest impact in tropical countries. In Central America, multiple hazards suppress growth opportunities.

A Role for Earth Science in Improving Human Well-Being

Human well-being and Earth's natural systems share a relationship that is complexly codependent, regionally diverse, often indirect, subtle, and nonlinear. Although clear correlations exist, they do not establish to what extent the correlations describe outcomes or causes of poverty. A basic research question is: How does the condition of the Earth govern and limit human well-being? This research domain lies on the boundary between natural Earth sciences and the social sciences, including economics. The research demands skills well known to Earth scientists, including spatial data analysis, time series analysis, inverse methods, observation and monitoring, and statistical analysis applied across data sets from both the natural sciences parameterizing Earth systems, and social science data that describe human systems.

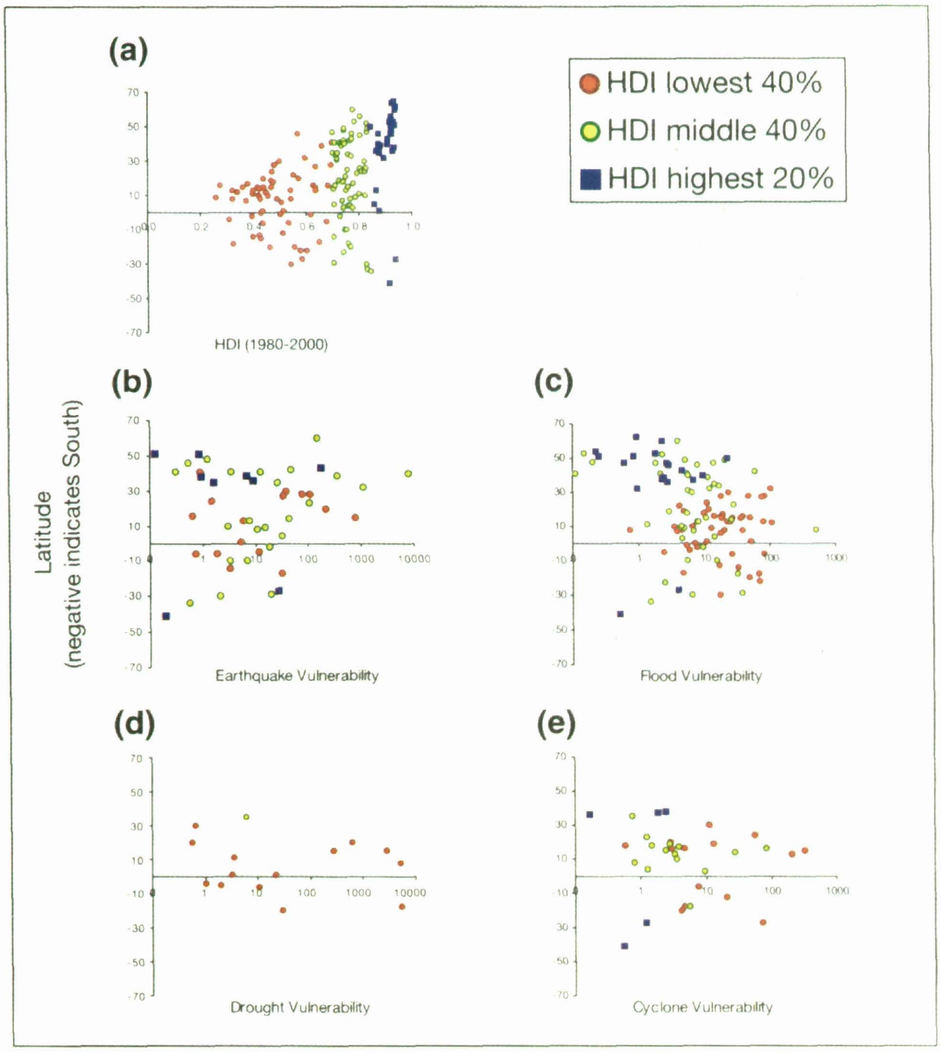

Fig.3. (**a**) HDI against latitude (north positive) shows the great prevalence of low HDI countries in the equatorial regions. Countries with lowest HDI are generally located near the equator: The color division is the same as in Figure 1 and is used in the subsequent figures. Figures 3(**b**), (**c**), (**d**), and (**e**) show vulnerability (defined as the number of people killed per million exposed to a particular hazard) for earthquakes, floods, droughts and cyclones using data presented by the UNDP (2004; http://www.undp.org/bcpr/). For flood vulnerability (3c) there is a clear separation between high HDI countries (blue) and low HDI countries (red), with the lower countries generally being much more at risk. These plots do not account for the relative severity of the natural events. Rainfall, and hence floods, are more intense in the tropics, but low HDI countries are one or even two orders of magnitude more at risk than high HDI countries; a difference that greatly exceeds the relative severity of natural hazards in these regions. Droughts that cause mortality (3d) are almost exclusively a poor world phenomenon. Earthquake vulnerability (3b) should have no natural latitude dependence and the results are more scattered, but a tendency for the richest to be least vulnerable remains. Note that these compilations do not include recent earthquakes in Gujarat, India and Iran, flood deaths in Haiti, or the Asian tsunami disaster that would serve to enlarge the differences between rich and poor.

The research, which is most pertinent to the world's poorest societies, is unlikely to occur there, where science of any sort is virtually absent. What is needed is an effort like the Commission on Macroeconomics and Health, launched by the World Health Organization in 2000. The commission produced a 2001 report, with Jeffrey Sachs as lead author, that established the dual nature (both cause and consequence) of disease burden on poor people.

Participation by stakeholders from poor countries is essential to building their capacity to conduct research. The U.S. National Science Foundation and other granting agencies must develop programs targeted toward issues of the poor world. The AGU and other scholarly societies can also take up the challenge (e.g., J. C. Mutter et al., Earth science, human well-being, and the alleviation of global poverty, session presented on 14 December at the 2004 AGU Fall Meeting, San Francisco, California).

In addition, individual scientists in this rich society must develop research programs that will help to improve the condition of so many who have so little and need so much.

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References

BROWN, V.M.A. ISSAK, M. ROSSI, P. BARBOZA and A. PAUGAM (1998) Epidemic of malaria in northeastern Kenya, Lancet, v.352(9137), pp.1356-1357.

CANE, M., S.E. ZEBIAK and S.C. DOLAN (1986) Experimental forecasts of El Nino. Nature, v.321, pp.827-832.

ECONOMIST (2004) Food for thought, pp.67-79, 31 July.

GALLUP, J.L. and J.D. SACHS (2001) The economic burden of malaria, Am. Jour. Trop. Med. Hyg., v.64(1-2), Suppl., pp.85-96, Jan./Feb.

GILLES, H.M. (1993) The malaria parasites, in Bruce-Chwatt's Essential Malariology, 3rd ed. edited by H.M. Gilles and D.A. Warrell, pp.12-34, Edward Arnold, London.

LANDES, D.S. (1998) The Wealth and poverty of Nations: Why Are Some So Rich and Others So Poor?, 544p., WW Norton, New York.

MUTTER, J.C (2004) Hurricane havoc, Op.-Ed. page, Miami Herald, 6 Oct.

SACHS, J.D., J.L. GALLUP and A. MELLINGER (1999) Geography and economic development, in Annual World Bank Conference on Development Economics: 1998, edited by B. Pleskovic and J. E. Stiglitz, World Bank, Washington, D.C.

SACHS, J.D. (2005) The End of poverty: Economic Possibilities for Our Time, 396p., Penguin, New York.

SACHS, J. D., J.W. MCARTHUR, G. SCHMIDT-TRAUB, M. KRUK, C. BAHADUR, M. FAYE and G. MCCORD (2004) Ending Africa's poverty trap, in Brookings papers on Economic Activity 1:2004, edited by W.C. Brainerd and G. L. Perry. Brookings Inst. Press, Washington, D.C.

THOMSON, M.C., S.J. CONNOR, T. PHINDELA and S.J. MASON (2005) Rainfall and sea-surface temperature monitoring for malaria early warning in Botswana, Am. Jour. Trop. Med. Hyg., in press.

ZOBACK, M. (2004) Why must earthquakes be this devastating?, Los Angeles Times, B5, Sunday 4 Jan.

3-D VISUALISATION OF GEOLOGICAL PROCESSES

Scientific studies have seen significant advances in the use of interactive 3-D visualisation display systems and software. For example scientists at the Scripps Institution of Oceanography Visualisation Center (SIO VizCenter – www.siovizcenter.ucsd.edu) use the Fledermas software developed by Interactive visualisation Systems (www.ivs3d.com) to create three dimensional scene files of various geophysical datasets. One such scene developed by Atuly Nayak and Dr. Debi Kilb at the SIO VizCenter shows the location of major earthquakes in Sumatra, the previous seismic activity, the fault rupture and sensor networks used to gather the data. This file (also published in the Eos April 5, 2005) can be downloaded from http://siovizcenter.ucsd.edu/library Tsunami/tsunami.htm and viewed with the free software application called iView3d (http://www.ivs3d.com/products/iview3d). Viewers can rotate, zoon in and out, and pan around the dataset. 3-d interactive visualisations can be used as a powerful research and teaching tool, to analyze any dynamic geological system in three dimensions, such as fault movement, landslides, magma movement, aquifer dynamics, earthquakes, ore deposit formation etc. A spectacular DVD of 3-D visualisation of various geological processes and natural phenomenon (including the Sumatra earthquake) can be obtained from Atul Nayak (anayak@ucsd.edu) free of charge.

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