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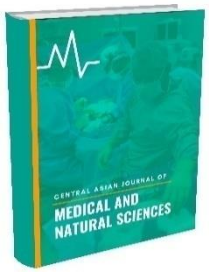

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Impact of Ecology on Health

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Abstract: Human activity is rapidly transforming most of Earth's natural systems. How this transformation is impacting human health, whose health is atgreatest risk, and the magnitude of the associated disease burden are relatively new subjects within thefield of environmental health. Wediscuss what is known about the human health implications of changes in the structure and function of natural systems and propose that thesechanges are affecting human health in a variety of important ways. We identify several gaps and limitations in the research that has been doneto date and propose a more systematic and comprehensive approach to applied research in thisfield. Such efforts could lead to a more robustunderstanding of the human health impacts of accelerating environmental change and inform decision making in the land-use planning,environmental conservation, and public health policy realms.

Key words: Hippocrates, Anthropocene, conservation, ecosystem services, Millennium Development Goals, poverty alleviation.

At least since Hippocrates wrote On Airs, Waters, and Places, the natural environment has been viewed as an important determinant of human health. However, over the last century, the field of environmental health has focused increasingly on quantifying exposure–response relationships for toxins en-countered in the human-dominated environment: from an initial focus on workplace exposures, to a population-level focus on radiation, heavy metals, air and water pollution, and more recently, to exposure to endocrine-disrupting chemicals. Over this period, relatively little attention has been paid to how changes in the structure and function of Earth's natural systems might affect human health. Growing evidence that changes in these natural systems can affect human health in a variety of important ways and the increasing pace and extent of these changes has prompted this Perspective. In it, we review current understanding of this field, identify some of its gaps and limitations, and suggest an approach to expanding our understanding. Human activity is transforming nearly all of Earth's natural systems. With the human population now exceeding 7 billion people and rapid growth in per capita consumption of goods and services, humanity's growing ecological footprint is altering the planet's land cover, rivers and oceans, climate sys-tem, biogeochemical cycles, and the function-ing of its ecosystems (1). This suite of changes has given rise to the definition of a new geo-logical epoch: the Anthropocene (2).The arrival of the Anthropocene presents an uncertain future, not only for the

biosphere, but for humanity itself. There is widespread debate about the ability of an altered global environment to meet the needs of a growing and prospering human population. Health is one dimension of human well-being that has received particular attention in this discussion. In 2005, for example, 1,360 experts from 95countries produced The Millennium Ecosys-tem Assessment (MA), a consensus document evaluating the state of the planet's ecosystems. The authors concluded that "any progress achieved in addressing the Millennium Development Goals of poverty and hunger eradication, improved health, and environmental sustainability is unlikely to be sustained if most of the ecosystem services on which humanity relies continue to be degraded"(3). At the same time, the Director-General of the World Health Organization underscored that "Nature's goods and services are the ultimate foundations of life and health"(4).Despite the intuitive importance of natural systems to human health, the empirical evidence to support these claims has been relatively thin. On one hand, natural systems provide a suite of "ecosystem services "including nutrition, purification of water, protection from natural hazards, and reduction of some infectious diseases (3). On the other hand, ex-tensive human alteration of the natural world has coincided with large improvements inmost health indices globally. Here we explore our current understand-ing of the human health impacts of alter-ations in the structure and functioning of Earth's natural systems. Our goals are to (i)illustrate what is currently known, (ii)identify gaps and limitations that can be addressed by future research efforts, (iii)address the scale of the health burden associated with changes to natural systems, and (iv) propose a research approach that strengthens the practice of both public health and environmental conservation.

Other reviews have laid out a more complete summary of the existing literature than we intend here (5). As these reviewers have noted, the literature exploring connections between human health and ecological alteration includes multiple studies scattered across a variety of disciplines that leave many of the most important relationships incompletely characterized. Despite its patchy nature, in aggregate, this work is convincing tha there are significant linkages between the structure and function of natural systems and a variety of human health outcomes. Here, we provide an overview of the types of relation-ships that have been well studied and established as a prelude to exploring the gaps, limitations, and areas requiring further study. With roughly half the temperate and tropical forests cut down, nearly half the ice-free, desert-free terrestrial landscape converted to croplands or pasture, and more than800,000 dams impeding the flow through more than 60% of the world's rivers, alterations to our planet's land use and land cover represent some of the most pervasive changes humanity has made to Earth's natural systems(1). Some of these changes have clearly been associated with public health benefits. Early efforts to reduce malaria in the Tennessee Valley (6) and countries in sub-Saharan Africa including Nigeria (7) by draining swamps that were habitat for mosquito vectors, for exam-ple, proved very successful. The primary motivation for deforestation, dams, and irrigation projects in many parts of the world has been to increase the supply of food and clean energy—critical building blocks for public health. However, some of the negative impacts of land-use change have become clear more recently. Dams and irrigation projects cause very large increases in the prevalence of schistosomiasis (8–10) and malaria (11, 12)in parts of Africa and South Asia. They also increase exposure to other vector-borne diseases associated with significant morbidity and mortality including Rift Valley fever, filariasis, leishmaniasis, dracunculosis, on chocerciasis, and Japanese encephalitis (13–16). Deforestation increases exposure tomalaria in Africa (17–21) and South America(20–26) but has less predictable impacts in Asia(27–31) where therearem any more Anopheles vectors with less generalizable responses toreduced forest cover. In parts of Africa, forest cutting also alters the composition and density of aquatic snail species in a manner that favors transmission of schistosomiasis (32).Some land-use changes affect disease exposure less directly. In Belize, for example, nutrient enrichment with nitrogen and phos-phorus from agricultural runoff hundreds of miles upstream causes a change in the vegetation pattern of lowland wetlands that favors the more

efficient malaria vector Anopheles vestipenn is over the less efficient vector Anopheles albimanus, leading to in-creased malaria exposure among coastal populations

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