LAND-USE, LAND-COVER CHANGES AND GLOBAL AGGREGATE IMPACTS

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Summary

The current scientific and policy interest in land-use and land-cover change draws from its contribution to global change. Although environmental change occurs first, an intricate web of demographic, economic, and social changes ensue that feedback to the environment. These direct, indirect, and induced, local to global, short- to long-term, systemic and cumulative, reversible or irreversible impacts threaten the long-term viability and sustainability of natural and social systems.

Environmental impacts concern mostly changes in: (a) climate, atmosphere, and stratosphere (e.g., global warming and climate change, atmospheric pollution and stratospheric ozone depletion caused by the removal of Earth's vegetative cover); (b) water resources (e.g., water depletion and pollution due to agricultural intensification, overgrazing, and industrial activities); (c) soils (e.g., erosion, sedimentation, and desertification caused by removal of vegetation, water depletion, and climatic change); (d) ecosystems (e.g., mainly biodiversity loss); and (e) human health and safety (e.g., increased incidence of infectious diseases, accidents, and other health hazards due to inadequate water, food, and other resources.)

Demographic impacts include out-migration and weakening of population structures,

while economic impacts refer to loss of land productivity, increased cost of land utilization, reduced income, and dependence of economically marginalized regions on external sources for subsistence and development. Social impacts, in addition to health and safety, concern loss of wealth, job, education, and life opportunities, poor social status, nutrition, and living conditions; aggregately, environmental security and human vulnerability are placed at risk. All impacts combined suggest that, in the late twentieth century, land-use and land-cover change does not promote the broad goal of sustainable development. Extant and proposed policies to promote the transition to sustainability aim at controlling land-use and land-cover change, directly or indirectly. However, the complexity and systemic nature of impacts deem imperative the adoption of the precautionary principle and international-level policy action.

1. Introduction

Land-use and land-cover changes affect directly and indirectly the environment, economy, and society at various spatial and temporal levels. Although their impacts have been recognized long ago, especially after the Industrial Revolution, they became a cause of worldwide concern since the second half of the twentieth century. Many of them are global in nature as local-level changes build up and combine to produce large-scale changes that cannot be mitigated by local-level actions alone. The result is an intricate web of impacts that threaten the long-term viability of natural and social systems; or, in other words, the sustainability of the total environment–society–economy system.

The sequence starts with land-cover modifications that alter the physical and chemical composition of environmental receptors (air, water, biota); these trigger a host of economic and social impacts that lead to further land-use and land-cover changes. Originally, most attention was paid to environmental impacts, but gradually the severity of socioeconomic impacts, including food security and environmental vulnerability, were recognized as well. Currently, the study of land-use change covers the whole web of intricately interlinked environmental and socioeconomic impacts in the broader context of the quest for sustainable development.

Land-use change occurs first at the level of individual land parcels and modifies land cover through proximate sources of change. These include forest clearing, fires, shifting or intensive cultivation, overgrazing or, more generally, over-harvesting of resources, construction of housing, tourist facilities, and infrastructure works, dredging and filling of wetlands, afforestation, national park designation, etc. Collective processes result from the aggregation of individual actions; these are known as deforestation, urbanization, suburbanization, urban sprawl, industrialization, nature conservation, and tourism development. Because of the connectedness of the environment, changes in one receptor reverberate on other receptors, generating large-scale effects. Examples of those include global warming and climate change, stratospheric ozone depletion, land degradation and desertification, soil salinization, river, lake and coastal pollution, acidification, or eutrophication.

Environmental impacts cause socioeconomic hardships such as loss of land productivity and, consequently, increased cost of land development and income loss, unemployment, poor and unhealthy living conditions and the like. To overcome these hardships, people pursue particular courses of action. Migration and rural exodus are common "escape" solutions, improvements in land-management practices is another option, technological solutions still another, while a variety of institutional measures may try to address and/or redress some of these problems such as land reforms, environmental and regulations, instruments, and institutions, and administrative restructuring.

Numerous hypotheses have been advanced to explain and predict the causes of land-use change and the resulting impacts. The complexity of real-world situations, in particular the pathways through which changes occur, as well as their global nature, defies theoretical schematization and permits only approximations to both their identification and measurement.

2. Typology of Impacts of Land-Use/Land-Cover Change

Impacts can be classified on the basis of several criteria, the most important of which include: thematic content, spatial scale, temporal scale, relationship of impact to its source, severity, scope of effects, and reversibility. Based on these criteria, Table 1 presents various types of impacts. It is noted that these are not mutually exclusive in general.

Criterion	**Types of impacts**
Thematic content	Environmental, demographic, economic, socio-cultural
Spatial scale	Global, regional, local
Temporal scale	**Short, medium, and long-term**
Relationship of impact to its source	Direct, indirect, induced
Scope of effects	Systemic and cumulative
Reversibility	Reversible and irreversible

Table 1. Typology of impacts

The first grouping-environmental, demographic, economic, and sociocultural impacts-is self-explanatory. The second-lobal, regional, local-distinguishes impacts coarsely according to their spatial scope although the exact spatial meaning of the categories "regional" and "local" depends on the broader geographical context of reference. The same applies to the temporal categories of impacts.

Direct impacts flow from the immediate source of change to a receptor (groundwater quality drops when agro-chemicals are applied to cropland; water flows change after tree felling in a watershed; biodiversity decreases when forests are cleared). Indirect impacts are caused once direct ones have started to occur. Decreases in water quality bring about changes in aquatic fauna (e.g., extinction of sensitive species); soil erosion leads to sedimentation in lowlands, and so on. Productivity losses due to land degradation lead to income losses that reduce consumption and, hence, the demand for and prices of various products. Induced impacts are those that might not have appeared had not the direct impacts occurred. Land degradation may push people away from their places to other areas where they settle, causing land-use change with its consequent impacts, as it is the case of shifting cultivators in the Amazon region.

"Systemic" and "cumulative" impacts refer to a genetic typology of forms of global change introduced by Meyer and Turner. "Globally systemic impacts" refer to those situations where intervention at one point can affect the entire system, having direct repercussions on other parts of the globe. The term "global" refers to the spatial scale of operation or functioning of a system. In other words, these impacts are not necessarily caused by global-scale activities; instead, the impacts of an activity are global. A prominent example is the emissions of greenhouse gases (carbon dioxide, methane, etc.) that occur locally but affect the composition of the atmosphere over larger areas, leading to global warming and climate change.

"Globally cumulative impacts," sensu Meyer and Turner, are those that are local in domain but which are widely replicated and which, in sum, constitute changes in the whole human environment. Although they are not physically connected through a globally operating system, these changes can reach a global scale and status when their occurrence in many places adds up; i.e., they refer to the aerial or substantive accumulation of localized change. Examples include lake, river, and sea pollution from many small-scale activities, habitat destruction, species transfer, biodiversity loss, etc. Systemic and cumulative impacts may not be always clearly distinguishable as cumulative changes may lead to systemic changes.

Lastly, impacts may be reversible or irreversible depending on whether the assimilative capacity of the socio-environmental system is exceeded or not. Species extinction is an example of an irreversible impact. Forest regeneration after a fire is an example of a reversible impact. The time horizon within which impacts are considered is important in the determination of reversibility.

All types of impacts are interlinked and highly specific to particular local socio-environmental situations. Environmental impacts in one place may cause migration to distant places that will experience, subsequently, socioeconomic and land-use changes. Urbanization increases the pressures for intensification in surrounding as well as distant agricultural regions to meet the food needs of urban populations. Small and insignificant changes may show up as important long-term changes as it is the case with the so-called "chemical time bombs." Any analysis of the impacts of land-use change inevitably has to confront the whole complex of impacts in order to support the design of sensible and effective mitigation strategies.

3. Global Environmental Impacts of Land-Use/Land-Cover Change

3.1. Impacts on Climate, Atmosphere, and Stratosphere

The impacts of land-use and land-cover change on climate occur at all scales—global, regional, and local. The primary mechanism by which alterations in climate—and, more specifically, rising atmospheric and Earth temperatures—occur is through the increased concentration of greenhouse gases in the atmosphere; a phenomenon known also as the "greenhouse effect." High concentrations of these gases in the atmosphere trap the incoming solar energy, produce changes in atmospheric moisture through increased cloud formation, and inhibit the natural cooling of the atmosphere through the exchange of atmospheric gases. The result is an increase in Earth's temperature that may induce eventually a chain of impacts on other environmental receptors—water resources (rivers, lakes, estuaries, oceans, and ice caps), soils, and ecosystems—as well as a host of undesirable socioeconomic impacts.

The primary greenhouse gases are carbon dioxide, methane, and trace gases. Carbon is the basic chemical constituent of carbon dioxide and methane; hence, the central issue is to assess (and to reduce) the amount of carbon released from various types of land use in the form of these two gases. Carbon dioxide is released from forests and soils that are cleared for agriculture and pastures as well as (in greater quantities) from the combustion of fossil fuels, including energy use in agriculture and forestry and for household purposes. Conversely, it is absorbed from the atmosphere by forest regrowth. In other words, forests are both a source and a sink of carbon. In certain cases, afforestation—when carried out at the expense of natural ecosystems (peat land, pastures, Mediterranean maquis, etc.)—may contribute to net carbon fluxes in the atmosphere instead of contributing to carbon sequestration.

Methane is generated from land uses associated with livestock (cattle raising), storage of animal wastes, landfills, and rice production in flooded fields. It is also produced "naturally" in wetlands, including large-scale irrigated rice fields. Lastly, nitrogen oxide emissions are generated from fertilizer application on cultivated land as well from transportation (all means) and energy use in urban and industrial areas.

Penner has estimated that land-use activities related to arable cropping, cattle raising, forest management, or transportation are currently responsible for about one-quarter to one-third of the human releases of carbon dioxide in the atmosphere, most of the human releases of methane, and for more than half of the human releases of nitrous oxides. Therefore, the conversion of forests and grassland to cropland and urban uses, of agricultural land to forests, etc. directly affects the carbon balance and may contribute significantly to increasing the sources of GHGs and reducing their sinks; this leads eventually to excessive concentrations of these gases and to global warming. It should be noted that scientific uncertainty still surrounds the assessment of the carbon budget and the relative contribution of natural and anthropogenic sources as a factor of global warming.

Climatic change—associated with global warming—is expected to produce impacts that may cause further land-use and land-cover change. Rising temperatures in arid and semiarid regions affect the water balance and, thus, the ability of these regions to produce adequate quantities of agricultural products. Northern regions may experience the reverse effect—increases in precipitation and, thus, either increased agricultural production or modified land-use patterns. Overall, producers are expected to make land-use decisions to cope with the adverse impacts of a changing climate. The southern limit of Boreal forests in Scandinavia might move as well as the desert fringe in various parts of the world. Changes in the thermal regime of the permafrost might produce ice melt and sea-level rise. These changes in environmental conditions might influence the habitat of fauna, the boundaries of nature reserves, and the boundaries and state of muskeg, mires, and peat bogs.

Land-use and land-cover changes affect air quality at regional and local levels. Processes associated with urbanization, increased mobility and transportation infrastructure, deforestation, overgrazing, and industrial pollution produce changes in the physical and chemical composition of the atmosphere. This results in the generation of gases—carbon dioxide and monoxide, sulfur oxide, nitrogen oxides—and heat with adverse local and long-distance environmental and health effects.

Stratospheric ozone depletion—the thinning of earth's protective ozone layer in the stratosphere—is associated with the production and use of chlorofluorocarbons (CFCs) as refrigerants, aerosol propellers, in fire-extinguishing foams, and in the plastics industry. Land-use change may interfere where land is converted to industrial uses that produce or use CFCs. The Convention for the Protection of the Ozone Layer was adopted by the United Nations in 1985 with the aim to reduce (and even ban) the production and use of CFCs.

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Biographical Sketch

Helen Briassoulis is a professor at the Department of Geography, University of the Aegean, Lesvos, Greece where she teaches quantitative methods in geography. She holds a PhD in Regional Planning from the University of Illinois at Urbana-Champaign, USA. She specializes in environmental planning, policy analysis, and decision making. She has participated as coordinator and/or researcher in several research projects on environmental issues. She has published in scientific journals and books on land-use change, desertification, sustainable development indicators, the informal sector, multicriteria analysis, tourism planning, tourism and the environment, environmental planning theory, environmental analysis, and integrated economic–environmental analysis. She is reviewer in several scientific journals and member of the editorial board of *Environmental Management*. Her work includes a contribution to the Web Book of Regional Science published by the Regional Research Institute of the University of West Virginia entitled "Analysis of Land Use Change: Theoretical and Modeling Approaches" (<http://www.rri.wvu.edu/regscweb.htm>). She is co-editor (with Jan van der Straaten) of the book "Tourism and the Environment: Regional, Economic, Cultural and Policy Issues" (Dordrecht: Kluwer Publishers, 2000). Her recent research focuses on the development of a policy support framework to combat desertification in the Mediterranean member states of the European Union.