

GIS and Remote Sensing in Environmental Risk Assessment and Management



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INTRODUCTION

The sustainability of the global economy hinges upon the health of the earth's environment. Effective environmental risk assessment and management have become increasingly important. With the ever-growing global population and expanding demands of economic development, we consume more natural resources, produce more waste, and develop more extensively into the regions that are prone to environmental hazards.

Although humans have interacted with the environment for thousands of years, environmental risk assessment and management are only recent research undertakings. As industrialization has made the human-environment interactions more dynamic and complex, the increased environmental risks have propelled and compelled people to use technologies for mapping, monitoring and mitigating environmental problems.

The earliest environmental applications of major remote sensing and GIS technologies began in the 1960s, particularly marked by the successful launch of the TIROS-1, the first meteorological satellite, and the development of computer-based geographic information systems (GIS). The story *Silent Spring* (Carson, 1962) awoke the public's environmental consciousness and promoted public demands for governments to set up environmental protection policies and research priorities. The birth of the U.S. Environmental Protection Agency (EPA) in 1970 set the stage for modern environmental risk assessment. The launch of the LANDSAT program in 1972 created a new way for monitoring global land use and land cover changes (Foley, 1999; Goward et al., 2001; Aighewi et al., 2013; Hensen et al., 2013).

Remote sensing and GIS technologies have been applied in almost all of the major aspects of environmental studies, from natural hazards to human induced disasters, such as monitoring storms (hurricanes, tornados), land instabilities (earthquakes, volcanoes, landslides),

and water problems (tsunamis, inland floods, oil spills, water pollution), forest fires, land use and land cover changes and other ecosystem problems.

BACKGROUND

Environmental risks, ranging from natural to human-induced hazards, present growing threats to communities at different spatial and temporal scales. Effective and timely risk assessment and management has become part of the comprehensive approach to ensuring sustainable functions of modern civilization.

Remote sensing and GIS are geospatial information technologies that allow rapid data and information collection, integration and processing from various sources and formulating possible comprehensive strategies and even solutions to complex environmental problems. In particular, GIS and remote sensing together offer the capabilities of communicating analytical data from bio-physical and socio-economic areas into geographic-referenced images, maps and reports to decision-makers more effectively and timely.

Environmental professionals have increasingly utilized remote sensing and GIS to study human activities and the environment (Chen et al., 2003; Turner, 2003; Brown et al., 2012; Kokaly et al., 2013). Multi-spectral and multi-resolution sensors on different platforms have become our "eyes" in space, providing constant and consistent environmental surveillance. In the meantime, GIS has provided us with the extended processing "brain" power to store, analyze, and display unprecedented vast amount of complex data and information. The technological marriage of remote sensing and GIS created a powerhouse that allows remotely sensed data to be directly fed into GIS for integrated analysis and visualization. Satellite remote sensing provides a systematic and synoptic knowledge base about the earth's complex geophysical phenomena (Trallie et

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al., 2005). A GIS integrated approach can be used for the risk management of natural hazards (Chen et al., 2003; Levin & Heimowitz, 2012)

CURRENT STATE

Effective environmental risk assessment and management is a four-dimensional complex process (Figure 1). The output of the assessment process depends upon the prerequisite steps of comprehensive data collection, integration and analysis. Remote sensing is very critical in capturing the temporal dynamic and vicissitudinary nature of hazards. The essential environmental risk assessment database must encompass the measurements and associated information on hazard types, occurrence probability and frequency, intensity and magnitude, and their proximity to the human environment. Remote sensing technology offers functionalities to fully monitor and measure those environmental variables at various spatial, spectral and temporal scales (Kamal & Phinn, 2011; Lechner et al., 2012; Aighewi et al., 2013).

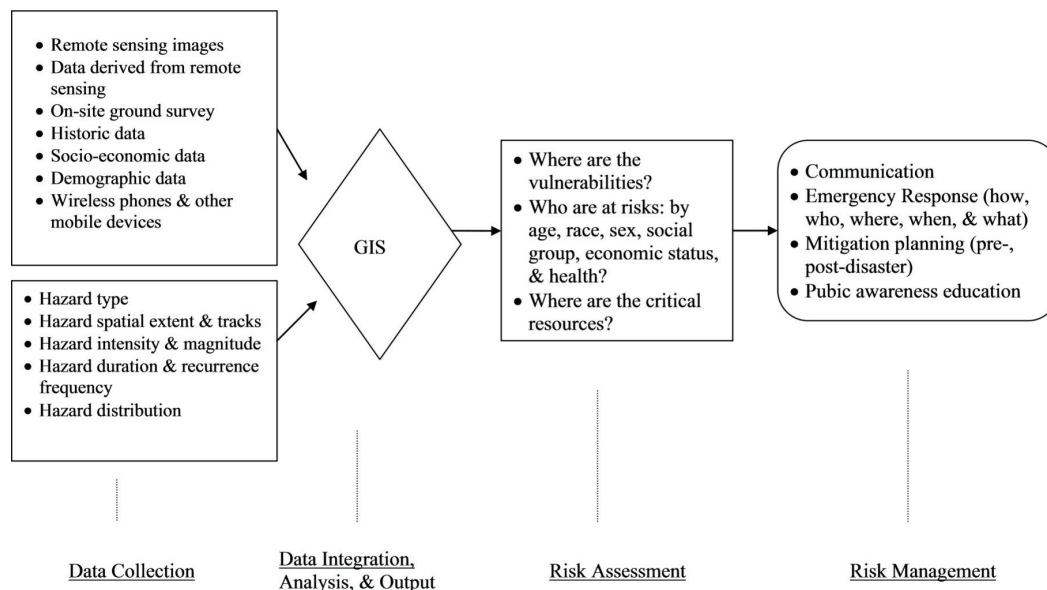
Spatially, over half of the global population are concentrated along the coastal zones (Finkl, 2000), about half of the population are clustered in cities (Thouret, 1999), especially in coastal cities. Eleven of

the world's 15 largest cities are on the coast (Cohen & Small, 1998). About 500 million people live close to active volcanoes (Thouret, 1999).

Multi-platform remote sensing allows environmental observations at different spatial scales (local, regional, and global) with varied spatial and spectral resolution (fine, medium, and coarse) at different time intervals. High spatial resolution imagery (of 5m to a few inches in pixel size) is used for precise topographic mapping and complex ecosystem change detection in densely populated regions (Ehlers et al., 2002; Ellis et al., 2006; Morsdorf et al., 2004; Klemas, 2013). Medium-resolution satellite imagery (5-100m) is utilized for diverse global environmental monitoring and assessment. Coarse spatial resolution satellite images offer nearly real time global weather and other dynamic events.

Data from many satellite imaging systems (Landsat, Seasat, IRS, SPOT, MODIS, IKONOS, GeoEye, EROS, LiDAR, etc.) have created new ways of monitoring fundamental land use and land cover changes and a variety of natural hazardous phenomena. For example, satellite images provide systematic observation data for assessing human risks to earthquakes, hurricanes, tornados, volcanoes, floods, landslides, coastal inundation (Klemas, 2013), oil spill, and forest fires (Mbow et al., 2004; Tralli et al., 2005; Levin & Heimowitz,

Figure 1. GIS and remote sensing in environmental risk assessment and management



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