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GIS and Remote Sensing in Environmental Risk Assessment

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INTRODUCTION

The existence, well-being, and sustainable development of the global economy hinges upon the state of the earth's environment. Effective environmental risk assessment and management issues have become increasingly important. With the ever-growing global population and expanding economic development, we consume more natural resources, produce more waste, and develop more areas into the regions that are prone to environmental risks. Although humans have interacted with the environment for thousands of years, environmental risk assessment and management is only a recent research undertaking. As the industrialization has made the human-environment interactions more dynamic and complex, the increased environmental risks have propelled and compelled people to use technologies for identifying and solving problems. The earliest global environmental applications of 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 the 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 environment 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, Masek, Williams, Irons, & Thompson, 2001).

BACKGROUND

Environmental risks ranging from natural to human-induced hazards present growing threats to communities at local, national, regional, and global scales. Effective and timely environmental risk assessment and management has become a forefront issue in ensuring the health and functions of modern civilization. Information technologies offer a promising approach of integrating and processing information from various sources and formulating comprehensive solutions to complex environmental problems. In particular, GIS and remote sensing technologies together offer the abilities of rapidly collecting data, processing and integrating data and information, and displaying results in geographic-referenced maps and reports. Environmental professionals have increasingly utilized remote sensing and GIS to study human activities and the environment (Chen, Blong, & Jacobson, 2003; Turner, 2003). Multi-spectral and multi-resolution sensors mounted on different platforms (aircrafts or spacecrafts) have become our "eyes" in space, providing constant and consistent environmental surveillance. In the mean time, GIS has provided us with the extended brain-power to store, process, analyze, and display unprecedented vast amounts of complex data. 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 (Tralli, Blom, Zlotnicki, Donnellan, & Evans, 2005). A GIS-based integrated approach can be used for the risk management of natural hazards (Chen et al., 2003).

CURRENT STATE

Effective environmental risk assessment and management is a complex process (Figure 1). The success of the process depends upon the prerequisite steps of comprehensive data collection, data integration, and analysis. Remote sensing is very critical in capturing the dynamic and vicissitudinary nature of hazards. The essential environmental risk assessment database must encompass the measurements and information on hazard types, occurrence probability and frequency, intensity and magnitude, and their proximity to the human environment. Remote sensing technology offers spatial, spectral, and temporal monitoring functionalities to fully measure these environmental variables.

Multi-platform remote sensing allows the earth's environment to be monitored at different spatial scales (local, regional, and global), spatial resolution (fine, medium, and coarse), and from a variety of spectral ranges beyond human's visible spectral vision (see Table 1). High resolution imagery (of 5m or less pixel size) is used for precise topography mapping and complex ecosystem change detection in densely populated regions (Ehlers, Gähler, & Janowsky, 2002; Ellis et al., 2006; Morsdorf, Meier, Kotz, Itten, Dobbertin, & Allgower, 2004). Medium-resolution satellite imagery (5-100m) is utilized for diverse global environment monitoring and assessment. For example, data from many

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

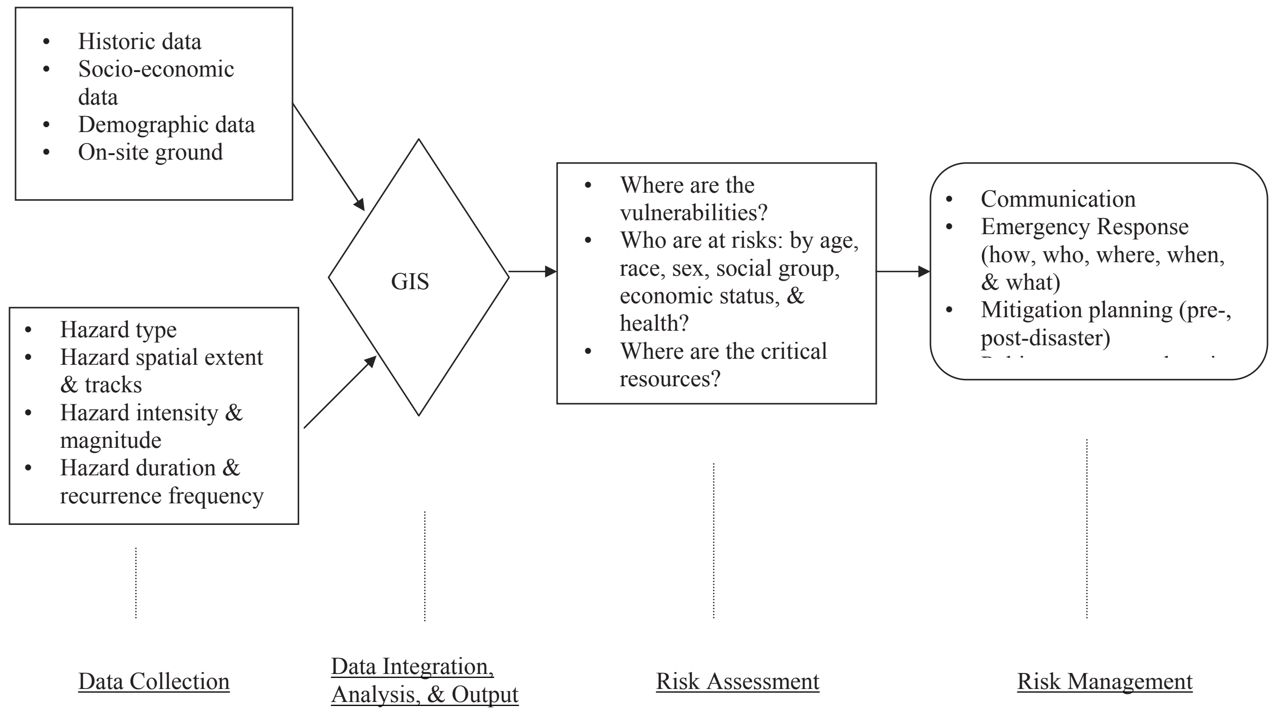

Table 1. Selected remote sensing application in environmental risk assessment

Remote Sensing Type		**Characteristics**	Environmental Risk **Assessment**
Platform	Aircraft	Local & regional coverage at certain time interval	A variety of environmental monitoring and assessment at relatively local levels
		low, medium, and high altitudes	
	Spacecraft (Shuttle & Satellite)	regional and global coverage	Monitoring the environment at regional or global levels in a long-term repetitive manner
		long term and repetitive surveillance	
		high & very high altitudes	
Sensor Spectral Range	Ultra violet (UV)	0.3–0.4 μm	Oil spills, wildlife inventory
	Visible	0.4–0.7 μm	Various land use and land cover assessment
	Near & mid infrared (NIR, MIR)	0.7–3 μm	Water and land boundary, vegetation differentiation
	Thermal infrared (TIR)	3–14 μm	Fire, volcanic activities, thermal pollution
	Microwave/RADAR	1 mm–1 m	Oil spill, deforestation, polar ice study
Sensor Spectral Resolution	Panchromatic mode	One broad band	Preliminary assessment
	Multispectral mode	Several to tens of broad bands with spectral range in μm	Comprehensive comparative study, feature discrimination
	Hyperspectral mode	Hundreds of narrow bands with spectral range in nm	Possible specific feature identification
Image Spatial Resolution	Fine resolution	Less than 5m	Precise and detailed study
	Medium resolution	5–100m	Local & regional study
	Coarse resolution	Greater than 100m, often in km	Sub-continental & global environment assessment