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GEOGRAPHY, DISASTER RECOVERY AND REMOTE SENSING

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ABSTRACT

The long term recovery of communities following a disaster is a complicated matter. Both the disaster experience and the recovery experience can be quite variable when considered at the community scale. A single event may impact different places in different ways. Differential recovery can depend on the vulnerabilities of the community prior to the event; the allocation of resources both before and after the event; as well as the socioeconomic and sociopolitical contexts within which the disaster and recovery take place. Considerable attention and research has focused on the response phase of the disaster cycle, this work explores the recovery and reconstruction phase of the cycle as an attempt to extend the application of remote sensing to long term recovery from disasters. Investigating the elements of recovery with remote sensing may aid in identifying recovery stages as well as monitoring the rate at which different places transition from one stage to the next. Preliminary observations and challenges are based on case studies of earthquake and hurricane disasters. The implications of such a remote sensing approach, or perhaps a remote sensing tool, extend to recovery resource allocation and efforts to support efficient and effective recovery – alleviating the common condition where the gap between the most and the least vulnerable before a disaster gets larger in the years and decades following the disaster.

INTRODUCTION

Disasters disrupt the lives and livelihoods of communities. Immediately following disasters the competing goals of rapidly restoring functionality and taking the opportunity to plan recovery efforts to minimize future losses confront communities and residents. Combined with that is the reality the population impacted by disaster may well recover at different rates depending on aid, magnitude of disruption, and pre-existing vulnerabilities. Recovery is a complex process acting over large areas that are potentially isolated by the disaster event. Because of the large areas that must be analyzed for recovery and based on the similarities between damage assessment and recovery monitoring, remote sensing is a logical tool for analysis of changes to an area throughout the recovery process.

While satellite image analysis has been applied to damage assessment and disaster management, it has yet to be applied to the recovery process. Such an application of remote sensing to recovery follows the logical sequence of the Emergency Management Cycle given that damage assessment precedes recovery in the disaster management process. Recovery is the least studied phase of the Emergency Management Cycle with previous studies focused on individual economic indicators of recovery. Therefore, based on these assumptions, this research is an initial attempt to answer the following questions:

- What are the sub-phases of the recovery process?
- What surface features or surface characteristics exist within sub-phase that may be resolved using remote sensing techniques?
- Which remote sensing techniques support the study of recovery?
- What lessons can be learned from the application of remote sensing to the process of recovery?

PHASES OF RECOVERY

While the phases of the Emergency Management Cycle are well known (preparedness, event, rescue, relief, recovery, and reconstruction before entering preparedness again), the sub-phases of recovery are less studied and less well-documented. Kates and Pijawka (1977) determined four sub-phases of recovery each with characteristic timing of events and actions (Table 1). The use of remote sensing in recovery requires a link between the Kates-Pijawka Model and the surface features to be resolved. Table 2 contains the characteristics of the sub-phases of recovery (Kates and Pijawka, 1977) with associated surface features that are indicators of each phase. The surface features listed within each sub-phase are not independent to that sub-phase but may be replicated throughout the process of recovery. As long term recovery progresses, target features to be identified may roll over into the next sub-phase. In addition, where possible and supportive, census data will be used to link surface feature analysis to economic data and sub-phases.

Table 1: The Four Sub-phases of the Kates-Pijawka "Model of Recovery Activity"			
Sub-Phase	**Timing**	**Characteristics**	**Denotes End of Phase**
Emergency	0 – 2 ½ weeks	• Coping actions relative to people and property • Normal social and economic activities are limited or stopped • May be a very short time period for some locations but for societies with limited coping activities, the emergency phase may continue much longer	• Completion of search and rescue, as well as the recovery of victims • Reduction in mass emergency shelter and feeding • Clearing rubble from main arteries
Restoration	1 – 20 weeks	• Utilities, housing, commercial and industrial structures are patched • Return to a relatively 'normal' level of social and economic activities • In those societies with coping mechanisms, this phase is over in months for other societies this phase may last for years	• Restoration of major urban services • Return of refugees • Most or all rubble cleared
Reconstruction I	10 – 200 weeks	• Also known as 'Replacement Reconstruction Period' • Capital stock and activities are rebuilt to pre-disaster levels • Social and economic actions are on-going at pre-disaster equivalents	• Population returns and resettles in the area and total population returns to pre-disaster numbers • Homes, job, capital stock and urban activities return to pre-disaster levels
Reconstruction II	100 -500 weeks	• Also known as 'Commemorative, Betterment and Developmental Reconstruction • Large, government funded construction projects to commemorate the event or better the community	• Completion of major construction projects
Source: Kates and Pijawka, 1977			

REMOTE SENSING AND RECOVERY

The difference between damage assessment using remote sensing and recovery monitoring using remote sensing is the timeframe. Damage assessment is conducted as a change detection before and just after the disaster event. Remote sensing for recovery monitoring, however, requires data to be collected at multiple occasions during the recovery process. Therefore the imagery analyzed should be collected according to the Kates and Pijawka (1977) recovery timeframe which is associated with data collection dates for two study events in Table 3. The images are acquired in accordance with availability, cloud cover, system configuration, and sensor issues.

Table 2: The Four Sub-phases of the Kates-Pijawka "Model of Recovery Activity" Related to Target Features		
Sub-Phase	**Surface Features**	**Activities**
Emergency	• Tents or emergency shelter • Large shelters or trucks used for emergency feeding and care • Damaged or destroyed facilities • Rubble • Ground cover • Ground vs. adobe buildings vs. rubble • Infrastructure issues (bridges, power stations, etc)	• Coping actions relative to people and property • Normal social and economic activities are limited or stopped • Completion of search and rescue, as well as the recovery of victims • Reduction in mass emergency shelter and feeding • Clearing rubble from main arteries
Restoration	• Rubble clearing and removal • Streets cleared • Rebuilding, reconstructing or refurbishing activity • Large earth moving equipment • Tents or emergency shelters • Temporary housing or shelter	• Utilities, housing, commercial and industrial structures are patched • Return to a relatively 'normal' level of social and economic activities • Restoration of major urban services • Most or all rubble cleared
Reconstruction I	• Rebuilding, reconstructing or refurbishing activity • Large earth moving equipment and/or construction equipment • New houses • New neighborhoods for resettlement • Rubble piles building up	• Capital stock and activities are rebuilt to pre-disaster levels • Population returns and resettles in the area and total population returns to pre-disaster numbers • Homes, job, capital stock and urban activities return to pre-disaster levels
Reconstruction II	• Large, new projects • New facilities • Expansion within and outside of the city	• Completion of major construction projects
Source: Kates and Pijawka, 1977		

Table 3. Kates and Pijawka (1977) "Model of Recovery Activity" Relative to Satellite Image Collection Dates		
Arequipa Earthquake Event	**Phase of the "Model of Recovery Activity"**	**Bhuj Earthquake Event**
June 23, 2001	**Event Date**	January 26, 2001
May 23 – June 22, 2001	**Pre-Disaster**	December 26, 2000 – January 25, 2001
January 24 – July 7, 2001	**Emergency 0 – 2 weeks**	January 26 – February 9, 2001
August 4 – November 17 2001	**Restoration 6 – 20 weeks**	March 9 – June 22, 2001
November 18 2001 – January 26, 2002	**Reconstruction A**	June 23 – September 1, 2001
January 27 – March 30, 2002	**Reconstruction B**	September 2 – November 2, 2001
June 15, 2002 onward	**Reconstruction C**	January 18, 2002 onward

Because of the similarities between remote sensing for damage assessment and recovery monitoring, similar image processing techniques can be applied to mark the changes in physical and cultural landscape over time. For example, Table 4 displays studies that have used remote sensing and image processing to the assessment of damage after earthquakes. The digital image processing techniques that are applicable to recovery monitoring are listed with each study.

Table 4. Research Related To Earthquake Damage Assessment, Disaster Management and Landslide Analysis

Topic	Study Area and Event	Data Source	Image Processing Techniques	Research Source
Damage Detection	January 13, 2001 7.6 M_w El Salvador	Landsat E-TM	• Hue, Saturation, Intensity Transformation of panchromatic and multispectral bands • Histogram Matching • Band averaging • Ratio of before image to after image (Change Detection)	Estrada et al., 2001a
Damage Detection	August 17, 1999 7.4 M_w Kocaeli (Marmara), Turkey	Landsat E-TM	• Image geometric transformation and image registration • Spectral profiling • Histogram matching • Normalized Difference Vegetation Index • Image subtraction for change detection	Estrada et al., 2001b
Damage Detection	August 17, 1999 7.4 M_w Kocaeli (Marmara), Turkey	Landsat E-TM	• Image geometric transformation and image registration • Spectral profiling • Histogram matching • Principal Components Analysis (PCA) for change detection • Change detection	Estrada et al., 2000
Disaster Response	August 17, 1999 7.4 M_w Kocaeli (Marmara), Turkey	SPOT 4 SAR Landsat TM	• Image geometric transformation and image registration • Image differencing for change detection • Correlation • Spectral profiling	Eguchi et al., 2003
Damage Detection	February 24, 2003 6.8 M Bachu, Xinjiang China	SPOT (10 m)	• Ratio • Subtraction • Correlation • Change detection	Xiazin and Ping, 2005.
Damage Assessment	May 21, 2003 6.8 M Boumerdes, Algeria	QuickBird	• Geometric transformation and image registration • Edge detection • Texture analysis • Difference and correlation for change detection	Adams et al., 2004a, 2004b
Damage Assessment	December 26, 2003 6.6 M Bam, Iran	QuickBird	• Image geometric transformation and image registration • Edge detection • Texture analysis • Difference and correlation for change detection	Adams et al., 2004a

DISCUSSION

This research contributes to developing an understanding of recovery as a complex process through the application of geographic techniques and perspectives. The geographic and social variability in recovery experiences reveals much about the pre-existing vulnerabilities of a place. The challenges in uncovering the complexities of long-term recovery are well matched to remote sensing data collection and data analysis techniques.

The advantages of the application of remote sensing technology to recovery are that it offers:

- Data collection and temporal alternatives to multiple site visits
- Opportunities to address the problems inherent in studying the multiple impacts of large, extreme events
- Data collection method that is unbiased, systematic, objective and unobtrusive data collection
- Methods of data analysis that are systematic and repeatable data analysis.

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