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Disaster Research Center

MISCELLANEOUS REPORT #69

UNCOVERING COMMUNITY DISRUPTION USING REMOTE SENSING: AN ASSESSMENT OF EARLY RECOVERY IN POST-EARTHQUAKE HAITI

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ABSTRACT. *This work is part of an exploratory study that seeks to describe the levels of community-scale building damage and socio-economic disruption following the January 2010 Haiti earthquake. Damage and disruption were analyzed for pre-event, post-event, and early recovery time periods in seven Haitian communities. Specifically here, remote sensing analysis related to early recovery and a remote sensing-based early recovery scale are presented. Damage datasets from the GEO-CAN post-disaster assessment were combined with analyses of fine resolution satellite imagery, captured 4 months after the earthquake, to quantify the early recovery status of damaged buildings. Disruption was established from community-level interviews conducted in May 2010. Preliminary results show little correlation between disruption and physical damage, although the integration of remote sensing, field data, interviews and community meetings was a successful approach for assessing disruption. Remote sensing was seen to be an effective tool in establishing levels of early recovery and supporting cross-community comparisons.*

1. INTRODUCTION

The 12 January 2010 Haiti earthquake displaced over 1.3 million, caused 300,000 lives to be lost, and caused US$7.9 billion in damage and economic loss (Government of the Republic of Haiti 2010). Others have estimated direct economic damage at US$7.2 to 8.1 billion (Cavallo et al. 2010). The losses and the consequent societal disruption have been extremely severe. This research provides an initial attempt to quantify and understand disruption at the community-scale, by focusing on physical damage and disruption and restoration of eleven sectors operating at the community scale for seven specific communities in Haiti (Figure 1). Among other study objectives, the project tests the application of remote sensing data, tools and techniques integrated with interviews as a way to establish and document community disruption due to disaster. While study communities were selected in part due to access and opportunity, they intentionally represent places that experienced different levels of ground-shaking and a range of damage levels. Across these communities, damage rates ranged from 2% to 21% of buildings either heavily damaged or collapsed, as calculated from post-disaster damage assessment data (Bevington et al. 2010) and remotely-sensed imagery collected for this study.

2. DATA AND METHODS

Damage and recovery data were primarily collected via remote sensing analysis (with field verification) and information on disruption was collected through field interviews conducted during a field deployment May 6 – 16, 2010. In the days after the earthquake, the Global Earth Observation

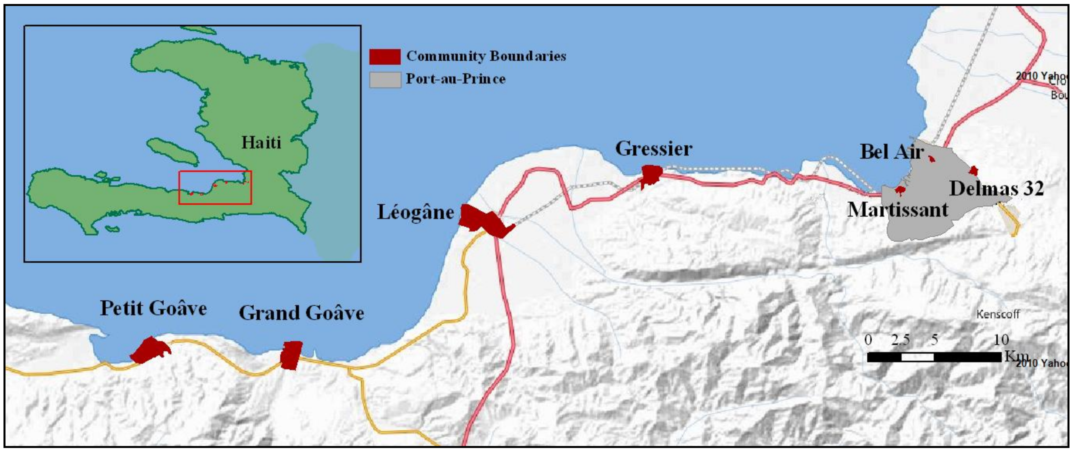


Figure 1. Locations of communities studied in Haiti

Catastrophe Assessment Network (GEO-CAN) brought together more than 600 remote sensing scientists and structural engineers to assess over 1000 km^2 of 15 cm optical aerial imagery (Ghosh et al. 2010). These data were independently verified using field validation and parallel damage assessment data from the United Nations Institute for Training and Research (UNITAR), Operational Satellite Applications Programme (UNOSAT), and the European Commission Joint Research Centre (JRC), and were made available to the international community during the Post-Disaster Needs Assessment (PDNA). The term "damaged" in this paper describes those buildings identified by GEO-CAN as having either sustained heavy damage, or collapsed—Level 4 or 5, respectively, EMS-1998 (Grünthal 1998). This was governed by a detection threshold where assigning damage levels below 4 was not consistently possible. For early recovery all buildings that were determined by GEO-CAN assessment to be damaged at level 4 or 5 were individually assessed in the imagery (Table 1). A recovery scale was used to describe changes that had taken place since the GEO-CAN damage assessment. Each damaged building, a total of 1679, was identified in the imagery and assigned a recovery score (Table 2). Ground-based observations collected

Table 1. Remote sensing imagery used for damage and early recovery assessment

[a] WorldView-1 has a spatial resolution of 50 cm (panchromatic), GeoEye-1 is 41 cm (multi-spectral), and WorldView-2 is 50 cm (multispectral).

Community	Pre-event (from Google Earth)	Post-event (GEO-CAN assessment)	Recovery[a]	Time from earthquake to recovery imagery
Bel Air	26 August 2009	15 cm aerial imagery (WB/ImageCat/RIT) (Google) 15-26 January 2010	GeoEye-1 11 May 2010	+17 weeks
Delmas-32	26 August 2009		GeoEye-1 11 May 2010	+17 weeks
Grand Goâve	31 August 2006		WorldView-1 22 April 2010	+14 weeks
Gressier	26 August 2009		WorldView-2 9 June 2010	+21 weeks
Léogâne	30 December 2005		WorldView-1 22 April 2010	+14 weeks
Martissant	26 August 2009		GeoEye-1 11 May 2010	+17 weeks
Petit Goâve	29 November 2005		WorldView-1 22 April 2010	+14 weeks

Table 2. Recovery scale used for analysis of early recovery

Recovery Score	Description
1	Structure unchanged since the earthquake
2	Structure intentionally demolished, but not cleared
3	<50% rubble removed
4	>50% rubble removed
5	Structure under construction
6	Structure rebuilt on same footprint
7	Structure rebuilt on different footprint

during the field deployment using GPS cameras and the VIEWS™ data collection system were used in the validation process for the early recovery remote sensing analysis (Figure 2). Analyses were conducted for the seven study communities selected to cover a range of damage extents (less than 2% - over 21% as illustrated in Figure 3) and to include both locations within Port-au-Prince and those outside of the capital city. Examples of the image analysis are shown in Figure 4.

Information on disruption was collected during the field deployment from a series of interviews with community representatives, NGOs, UN Clusters and utility agencies. Community-scale levels of disruption were approximated in terms of eleven sections (Hill et al. 2010): (1) drinking water, (2) energy/fuel/utilities, (3) sanitation, (4) education, (5) health care, (6) shelter, (7) food and food-

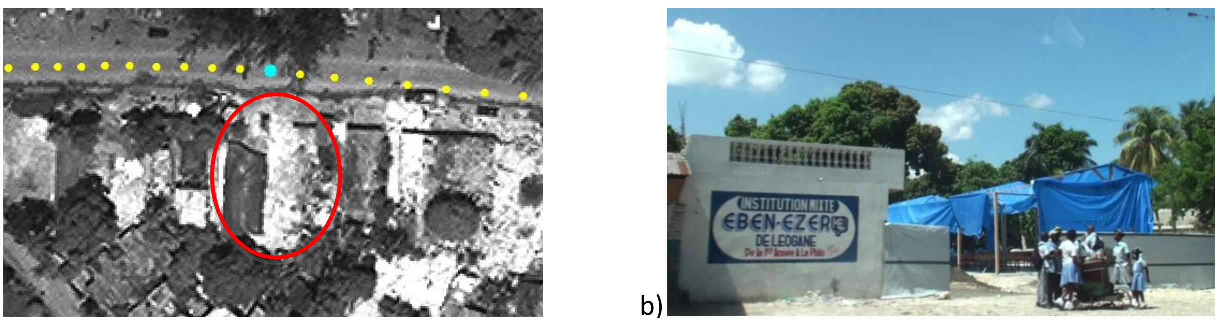
a)  b)

Figure 2. Field data collected using the VIEWS™ data collection system was used to validate remote sensing observations of recovery: a) satellite image of Léogâne with photograph location points overlaid. Circled area corresponds to land parcel shown in field data b).

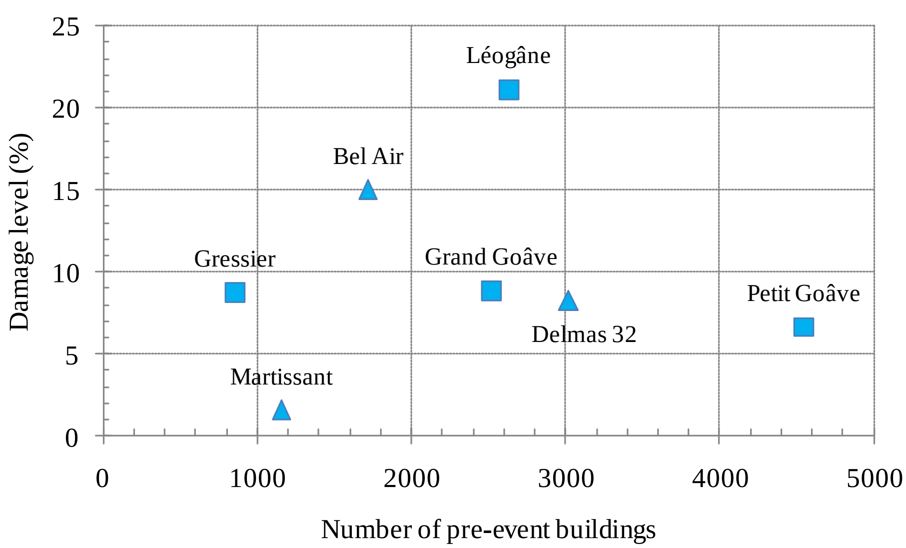


Figure 3. Community damage levels. Communities inside Port-au-Prince are depicted with ▲.

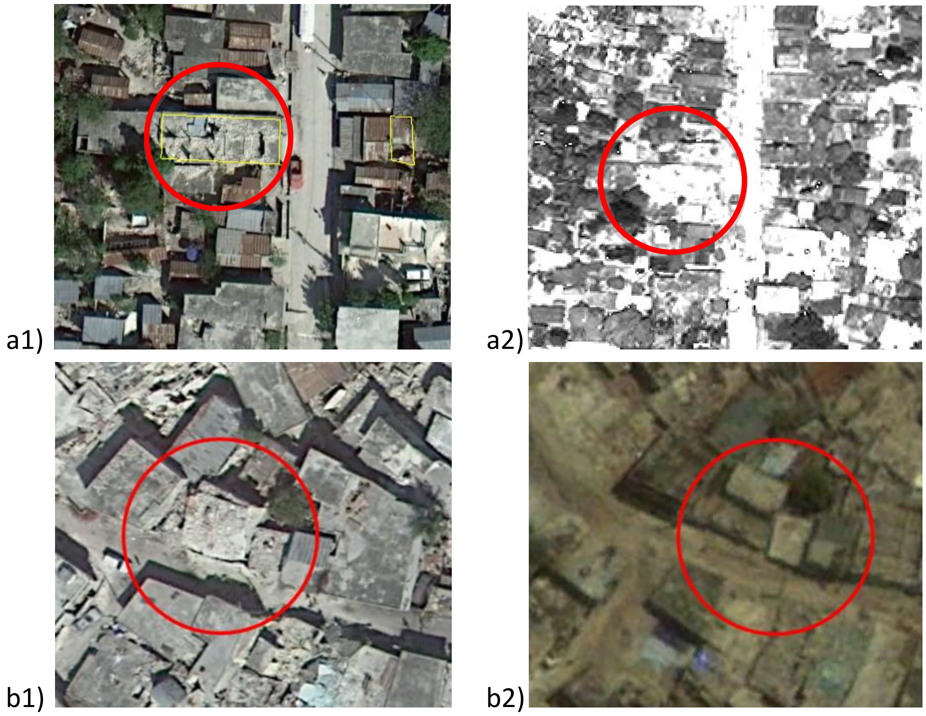


Figure 4. Examples of recovery analysis. a1) post-event aerial image showing level 5 damage. a2) WorldView-1 satellite image from May 2010 showing no change since January (Recovery score 1). b1) post-event aerial image showing level 5 damage. b2) Recovery score 7 – rebuilt on different footprint.

Meeting participants ranked the availability of sectors at times prior to, immediately following, 1-month following, and 4-months following the earthquake. The constructed scale for measuring sector status was a 7 point scale where: (1) represented no availability, (2) minimal availability, (3) poor availability, (4) moderate availability, (5) good availability, (6) almost full availability, and (7) represented full availability (see Hill, et al. for full descriptions of both sectors and scale). Meetings with NGO, UN clusters and utility organizations provided additional perspectives on community disruption but the ranking scale survey was not implemented in those settings.

3. FINDINGS

Building damage data reveal variation in damage levels across the studied communities: Léogâne (2630 buildings before the earthquake, 21% damage), Bel Air (1716, 15%), Grand Goâve (2518, 9%), Gressier (857, 9%), Delmas-32 (3018, 8%), Petit Goâve (4543, 7%), and Martissant (1154, 2%) (Figure 3 and Table 4). The change in damage state associated with the early recovery term (through spring 2010) as revealed through this remote sensing analysis suggests that recovery varies with place and that in general communities outside of Port-au-Prince have experienced less recovery than those inside the capital. This is evident by more "unchanged" buildings, fewer buildings cleared, and less debris removed (Table 4 and Figure 5).

In comparison, disruption rates (established from field interviews) reveal that pre-earthquake conditions were poor for all sectors with average ratings across all sectors and all communities rated at "moderate availability" (3.8/7). Immediately following the earthquake, and corresponding to the time damage assessments were conducted, substantial deterioration in service provision were wide-spread and represent significant disruption for communities (Table 4). Moving forward in time through the response and early recovery periods we see the restoration of services, in some cases to higher levels than before the event (Table 4).

Table 4. Comparison of damage, disruption and recovery over time by community. Information in non-shaded columns was derived from remote sensing. Shaded columns represent composite disruption scores (derived from Hill et al. 2010).

	Prior to event	Immediately after event (January 2010)		Early recovery (April-June 2010)		
Community	**Sector Availability Composite (max. = 7)**	**Damage (% of structures)**	**Sector Availability Composite (max. = 7)**	**Recovery Status: % Unchanged**	**Recovery Status: % Rebuilt (same or different)**	**Sector Availability Composite (max. = 7)**
Bel Air	3.9	15.0	2.1	33.1	0.2	3.4
Delmas-32	3.5	8.3	1.9	18.1	2.3	2.0
Grand Goâve	4.1	8.9	1.8	57.0	1.4	3.2
Gressier	3.8	8.8	2.1	53.3	0.3	2.8
Léogâne	3.6	21.1	1.7	60.0	1.0	2.5
Martissant	3.2	1.6	2.2	38.9	0.0	2.1
Petite Goâve	4.4	6.6	2.5	59.9	2.1	3.2

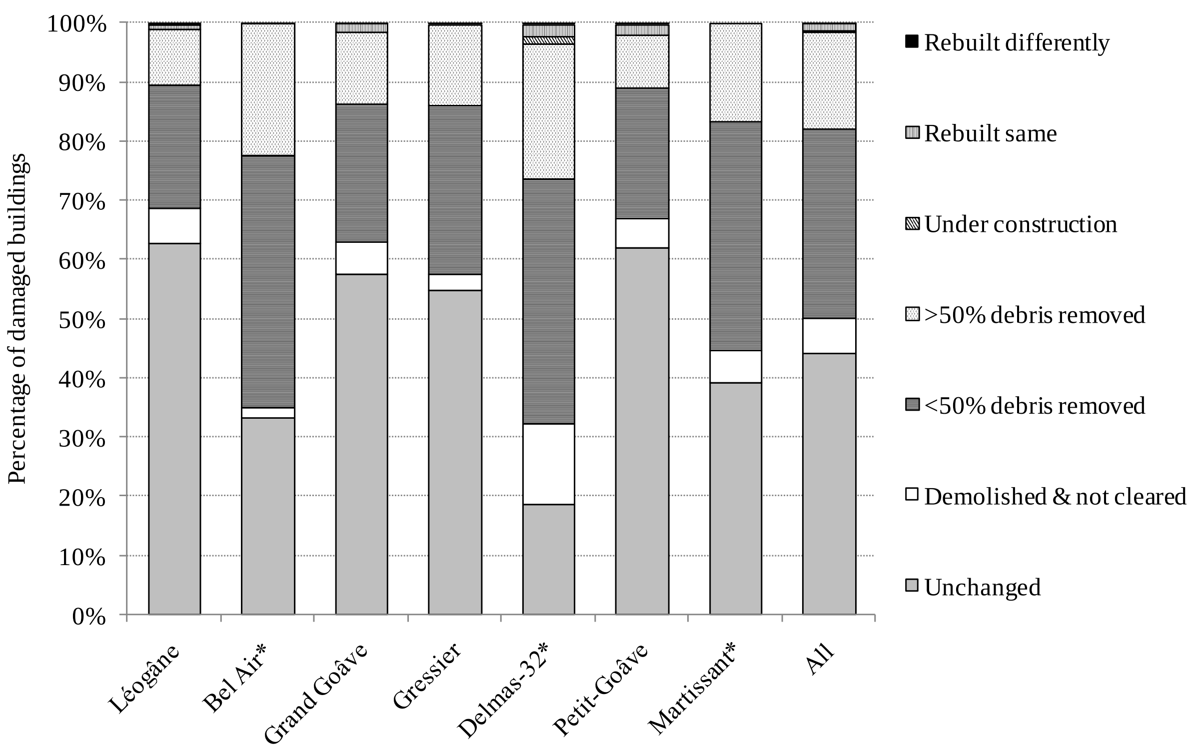


Figure 5. Percentage of heavily damaged or collapsed buildings in each stage of recovery as of spring 2010. Data generated from remote sensing analyses. Communities are ordered (l-r) from most to least damaged. *designates communities within Port-au-Prince.

4. SUMMARY

This project developed datasets for levels of damage, early recovery, and community disruption through integration of remote sensing, visual field data, interviews and community meetings. Remote sensing data and analysis techniques were fundamental to the effort – not only in damage and recovery assessment but also in study community selection and situational awareness. Remote sensing has limitations in terms of providing explanatory power necessary to understand changes in post-disaster landscape, but this was enhanced through the fusion of in-field disruption surveys. In a complex and disrupted environment, with physical and logistical restrictions in access, remote sensing has proved to be a valuable tool for describing recovery at the per-building level, whilst also providing a community-wide perspective. This gives a valuable insight, allowing recovery practitioners to identify early signs of intra-community variations in recovery. The fusion of data sources proved highly useful in this post-earthquake Haiti study and will be applied in subsequent investigations of community disruption here and in other cases.

ACKNOWLEDGEMENTS

NSF RAPID grant no. CMMI-1034876 supported the field visit to Haiti for disruption data collection, and purchase of imagery for this study. The authors appreciate assistance selecting, contacting and meeting with communities provided by colleagues and staff in the World Bank, Bureau de Monétisation et Programme d'Aide au Dévelopment and the Pan-American Development Fund. Residents generously shared their experiences and time with us, and their insights provide the basis for the disruption data used here.

REFERENCES

Bevington, J., Adams, B., Eguchi, R., 2010. GEO-CAN debuts to map Haiti damage, *Imaging Notes* **25**(2).

Cavallo, E., Powell, A., and Becerra, O., 2010. *Estimating the Direct Economic Damage of the Earthquake in Haiti*, working paper, Inter-American Development Bank.

Ghosh, S., Huyck, C., Greene, M., Gill, S., Bevington, J., Svekla, W., DesRoches, R., Eguchi, R., 2010. Crowd-Sourcing for Rapid Damage Assessment: The Global Earth Observation Catastrophe Assessment Network (GEO-CAN), *Earthquake Spectra*. Under review.

Government of the Republic of Haiti, 2010. "Action Plan for National Recovery and Development of Haiti," March.

Grünthal, G., ed., 1998. European Macroseismic Scale 1998. http://www.gfz-potsdam.de/portal/gfz/Struktur/Departments/Department+2/sec26/resources/documents/PDF/EMS-98_Original_englisch_pdf?binary=true&status=300&language=en.

Hill, A., Bevington, J. Davidson, R., Chang, S., Eguchi, R., Adams, B., Brink, S., Panjwani, D., Mills, R., Pyatt, S., Honey, M., Amyx, P., 2010. Community-Scale Damage, Disruption, and Early Recovery in the 2010 Haiti Earthquake, *Earthquake Spectra.* Under review.

Uncovering Community Disruption Using Remote Sensing:

An Assessment of Early Recovery in post-earthquake Haiti

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THE UNIVERSITY OF MEMPHIS

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NSF RAPID CMMI-1034876

STUDY OBJECTIVES

Investigate the application of remote sensing for assessment of early recovery.

Develop remote sensing-based building recovery scale.

Merge remote sensing assessment of early recovery with community perspectives of disruption.

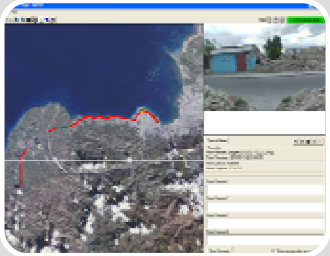
COMMUNITIES STUDIED

DATA COLLECTION

Field deployment in Haiti: May 6-16, 2010

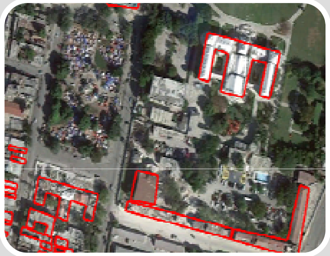
Interviews

- Community leaders
- Sector representatives



Field Data Collection

VIEWS™ & GPS Photos



Remote sensing

- GEO-CAN damage assessment
- Early recovery assessment

IMAGERY

Community	Pre-event (from Google Earth)	Post-event (GEO-CAN assessment)	Recovery	Time from earthquake to recovery imagery
Bel Air	26 August 2009	15 cm aerial imagery (WB/ImageCat/RIT) (Google) 15-26 January 2010	GeoEye-1 11 May 2010	+17 weeks
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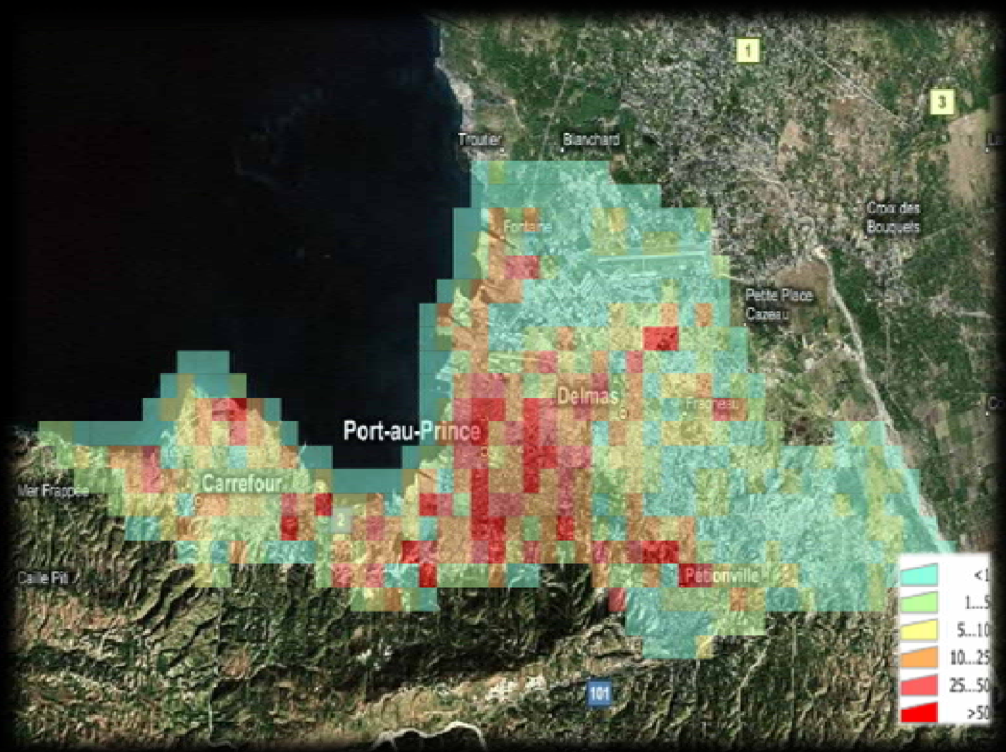
DAMAGE ASSESSMENT

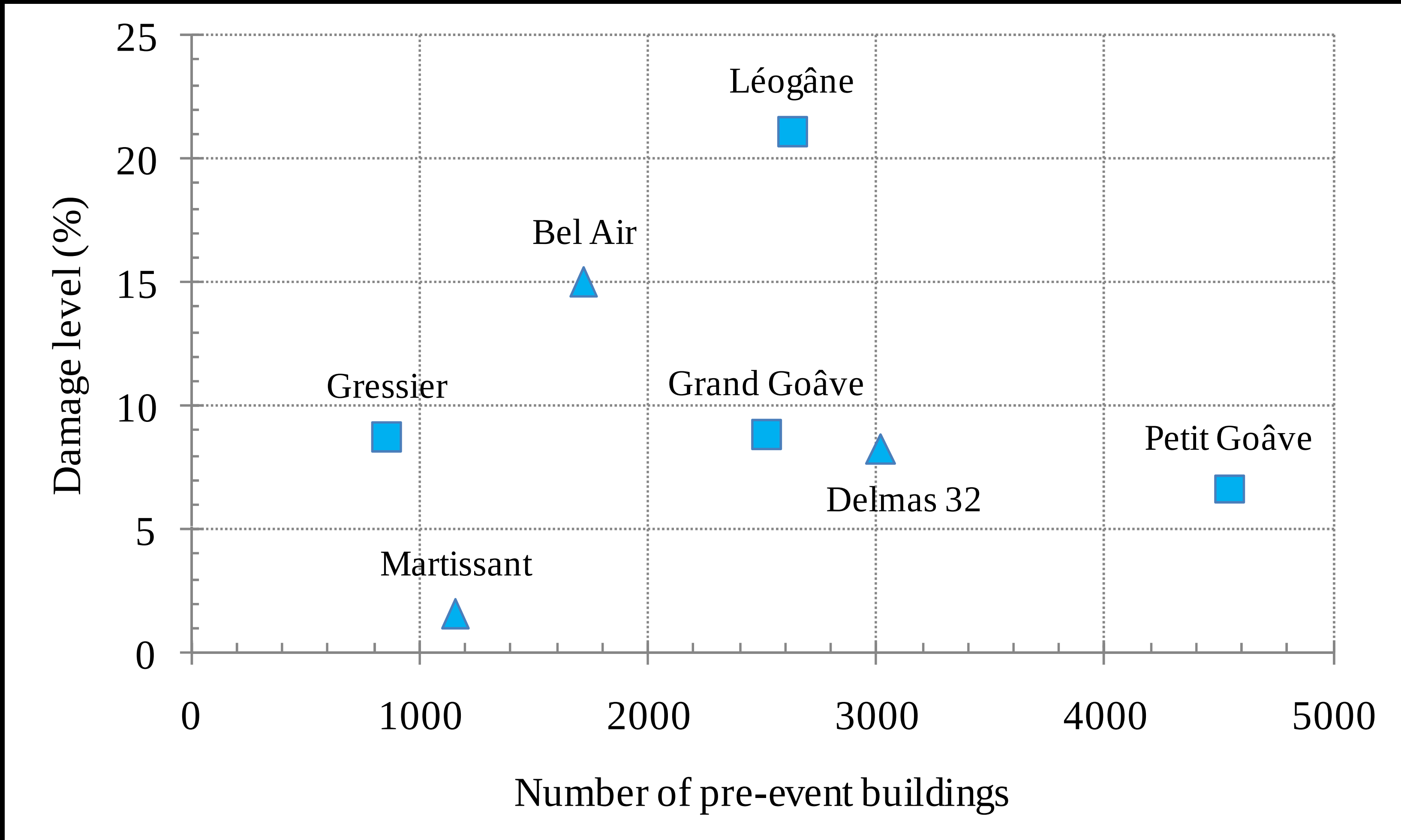
GEO-CAN initiative

Satellite and aerial imagery used for assessments

Identification of communities most affected by the earthquake.



DAMAGE TO STUDY COMMUNITIES



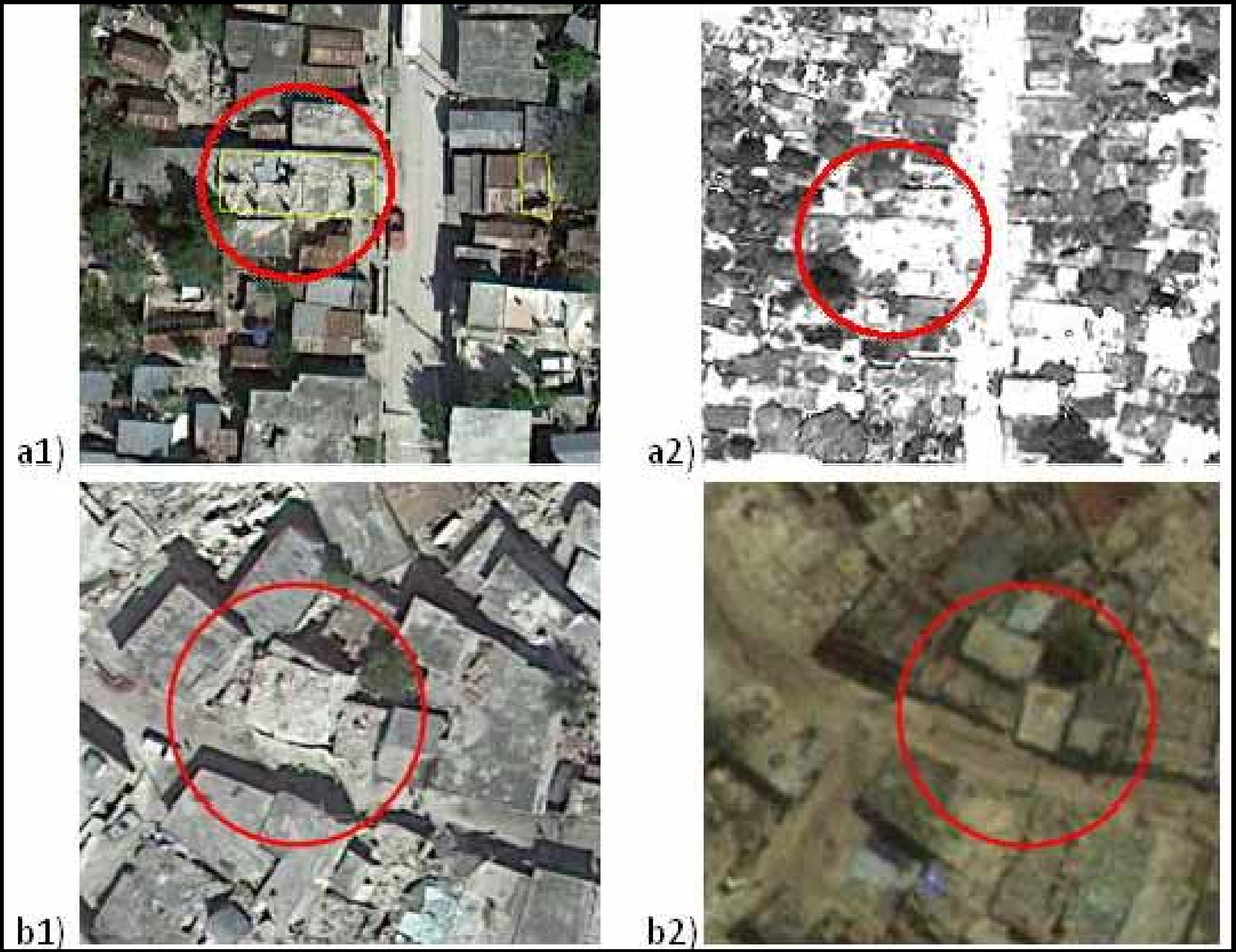
RECOVERY SCALE – per building

RECOVERY SCORE	DESCRIPTION
1	Structure unchanged since the earthquake
2	Structure intentionally demolished, but not cleared
3	< 50% rubble removed
4	> 50% rubble removed
5	Structure under construction
6	Structure rebuilt on same footprint
7	Structure rebuilt on different footprint

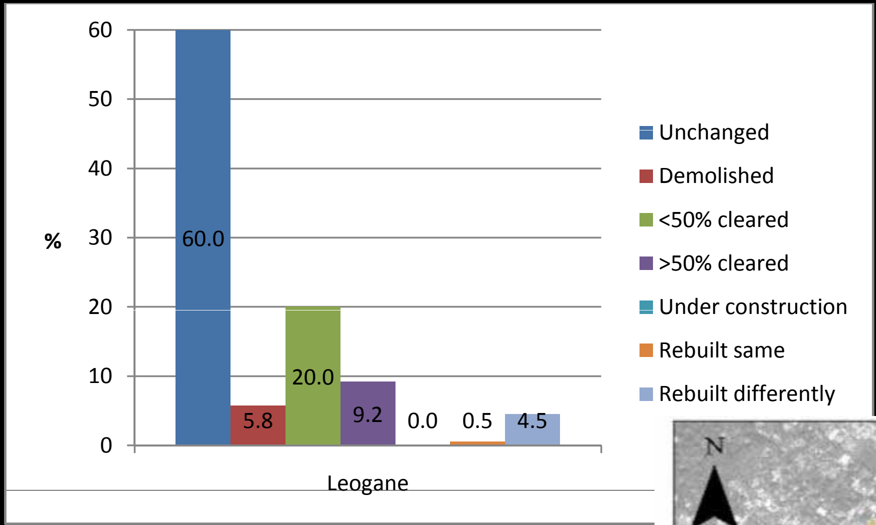
ASSESSMENT OF EARLY RECOVERY

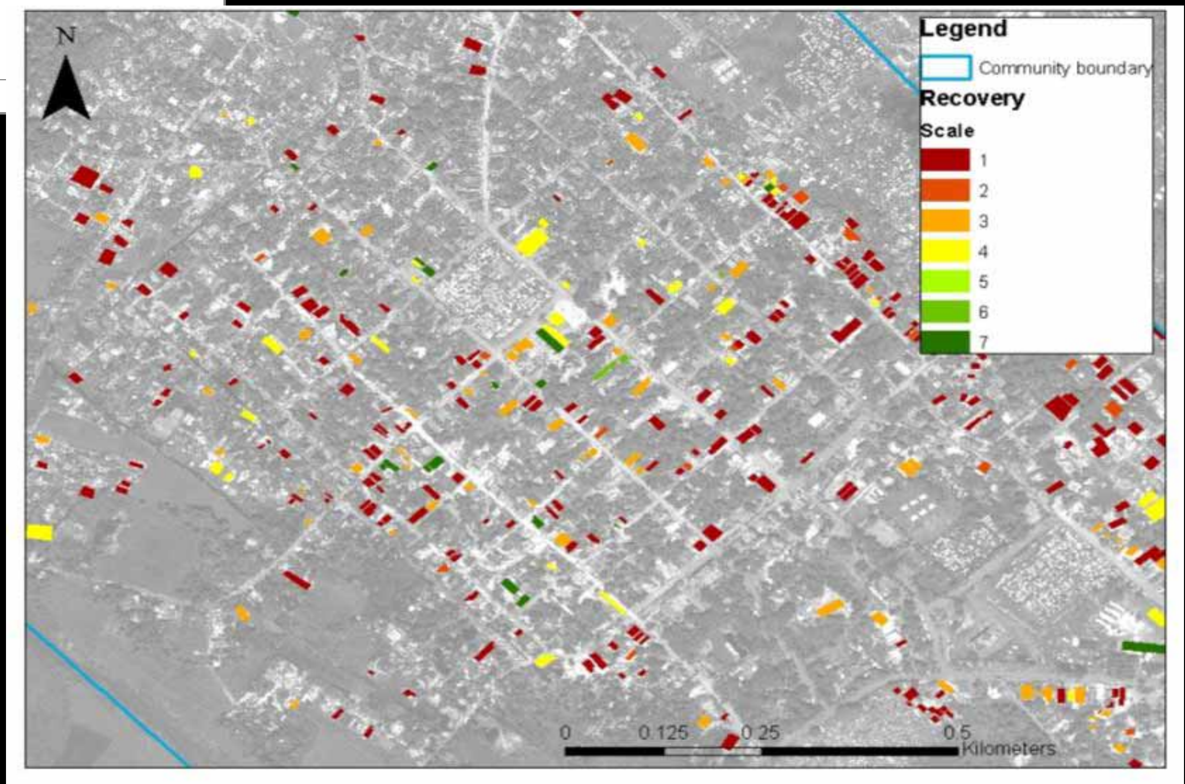
Satellite imagery used for assessments

GEO-CAN damage assessment used to target analysis

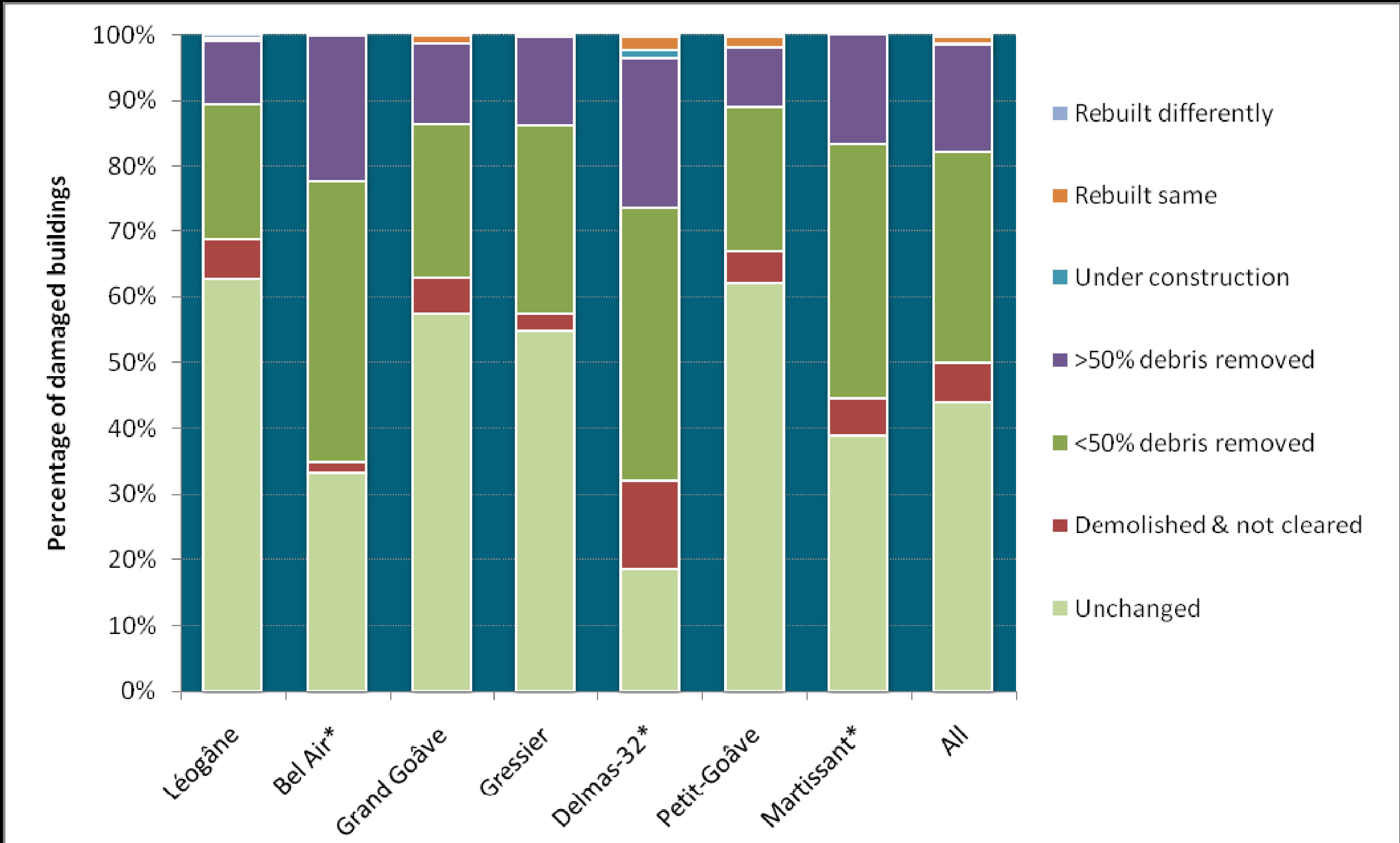


EARLY RECOVERY - FINDINGS





EARLY RECOVERY - FINDINGS



DISRUPTION
COMMUNITY MEETINGS

AVAILABILITY OF BASIC NEEDS

Constructed Disruption Scale

1 = **No** availability
Not available at even the lowest quality

2 = **Minimal** availability
Very unreliable, very poor quality, very insufficient, or inaccessible to most

3 = **Poor** availability

4 = **Moderate** availability
Available to some people who need it, though it may be inconsistent or of moderate quality

5 = **Good** availability

6 = **Almost full** availability

7 = **Full** availability
Available at consistent, high quality to everyone who needs it

Time Period Relative to 1/12/10 Earthquake

4 Time periods

	Prior to	Immediately following	1 month after	May 2010
Drinking water				
Food – stuffs and prep. equip.				
Shelter				
Sanitation				
Debris removal				
Fuel/energy/utilities				
Health care				
Education/schools				
Safety				
Livelihood				
Social networks				
Other				

11 Sectors

DISRUPTION AND RECOVERY

	Prior to event	Immediately after event (January 2010)		Early recovery (April-June 2010)		
				Recovery Status		
Community	Sector Availability Composite (max. = 7)	Damage (% of structures)	Sector Availability Composite (max. = 7)	% Unchanged	% Rebuilt (same or different)	Sector Availability Composite (max. = 7)
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FINDINGS

1. Remote sensing data and analyses are well suited to assessing early recovery of the physical landscape.

2. Limitations of techniques overcome through hybrid approach.

3. Variability in damage, recovery disruption with time and place observed and explained.

ACKNOWLEDGEMENTS

Colleagues and staff in the World Bank, Bureau de Monétisation et Programme d'Aide au Dévelopment and the Pan-American Development Fund.

Residents generously shared their experiences and time with us , their insights provide the basis for the disruption data used here.