SPATIAL VARIATION OF LIQUEFACTION-INDUCED GROUND SETTLEMENT USING LIDAR

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Liquefaction

Liquefaction is a common phenomenon that causes ground failure mostly in cohesionless and unconsolidated soils. It happens when pore water pressure and confining stress within soil column counteract each other. This counteraction is common when an earthquake happens.

Figure 1. Liquefied ground after 2011 New Zealand Earthquake (http://commons.wikimedia.org)

Liquefaction consequences and settlement

Liquefaction may induce a number of ground failures of varying severity, including: sand boils; ground cracks; lateral spreading; flow failures and ground settlement as loose, cohesionless soils tend to dilate during liquefaction. Settlement of the soil deposits is one of the most frequent subsequences of liquefaction (Ishihara, and Yoshimine, 1992; Tsukamoto et. Al, 2004); therefore, there is a need in engineering to estimate the range of settlement due to liquefaction with a dependable method. Vertical settlement can be developed by reconsolidation and densification of the liquefied soil layer and / or shear deformation due to lateral spreading. This research focuses just on the former one. Nowadays, Lidar (light detection and ranging) has become an established method for collecting very dense and accurate elevation values. Lidar is typically "flown" or collected from planes and produces a rapid collection of points (more than 70,000 per second) over a large collection area. Ground settlement may be measured by subtracting two Lidar data set captured at different time intervals.

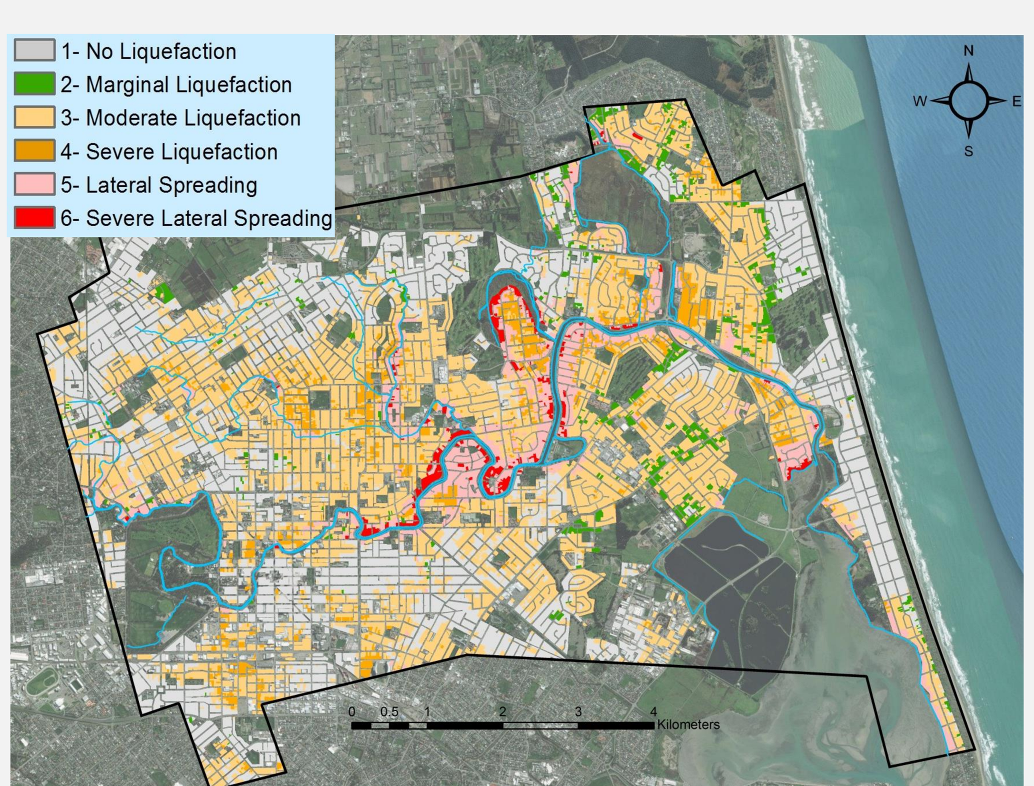

Figure 2. Liquefaction severity in Christchurch recorded by reconnaissance team after 22 February 2011 earthquake

The necessity of this research

Usually after earthquake-induced liquefaction happens in an area, the earthquake reconnaissance team will go on site and record the extent and severity of liquefaction. They will search every street and buildings and observe the damages due to earthquake. This process may take too long to accomplish and also needs a high number of human labor. If the high resolution lidar data would be available before and after an earthquake-induced liquefaction, then the changes in ground surface elevation can be measured by calculating the difference between the elevations of lidar data sets. This method can dramatically reduce time and cost in compare to measuring the liquefaction-induced settlement on site; however, the spatial variation of the lidar data should be accounted for. The lidar data usually have 7 to 10 cm of error. In this research, the goal is to observe the correlation between the reconnaissance team observation (reality) of liquefaction severity and the calculated liquefaction-induced settlement. It is expected that as the severity of liquefaction increases, the settlement also increases. In other words, the final goal of this study is to predict the severity of liquefaction based on the Lidar data.

Methodology and database

An earthquake of magnitude 6.2 shook the Christchurch area in New Zealand in 22 February 2011. An extensive liquefaction happened in the area because of that earthquake. Many structures experienced huge settlement and therefore failed and resulted in near 200 human casualties. The reconnaissance team after that went on site and recorded the liquefaction severity and categorized it into 6 different classes from 1 (no liquefaction) to 6 (severe lateral spreading or the most severe form of liquefaction). Also the Lidar data sets for before and after the event are available. The difference between the elevations of the two data sets represent the liquefaction-induced settlement. Using "zonal statistics" tool box in Arc Gis, the correlation between the lidar calculated settlement values (min, mean, max) for each property and the field observation has been plotted.

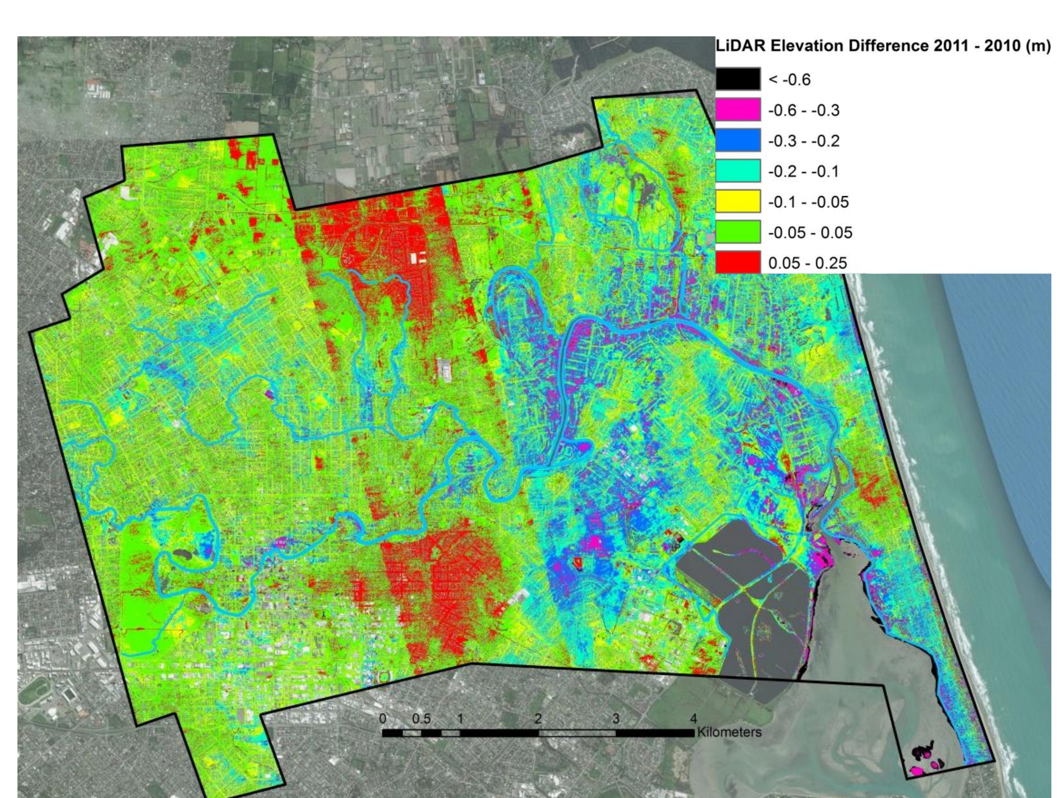

Figure 3. Lidar elevation data sets difference of the pre- and post-event

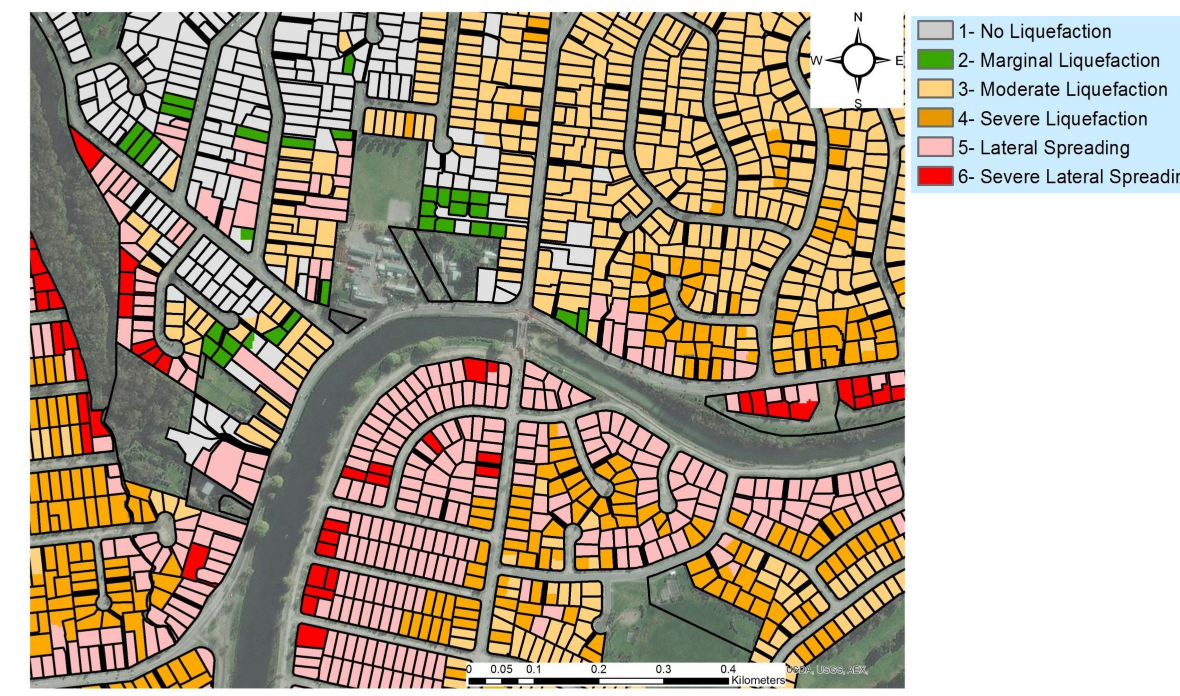

Figure 4. Field observation of liquefaction severity - close up scale

Figure 5. Minimum Lidar-calculated settlement for each property - close up scale

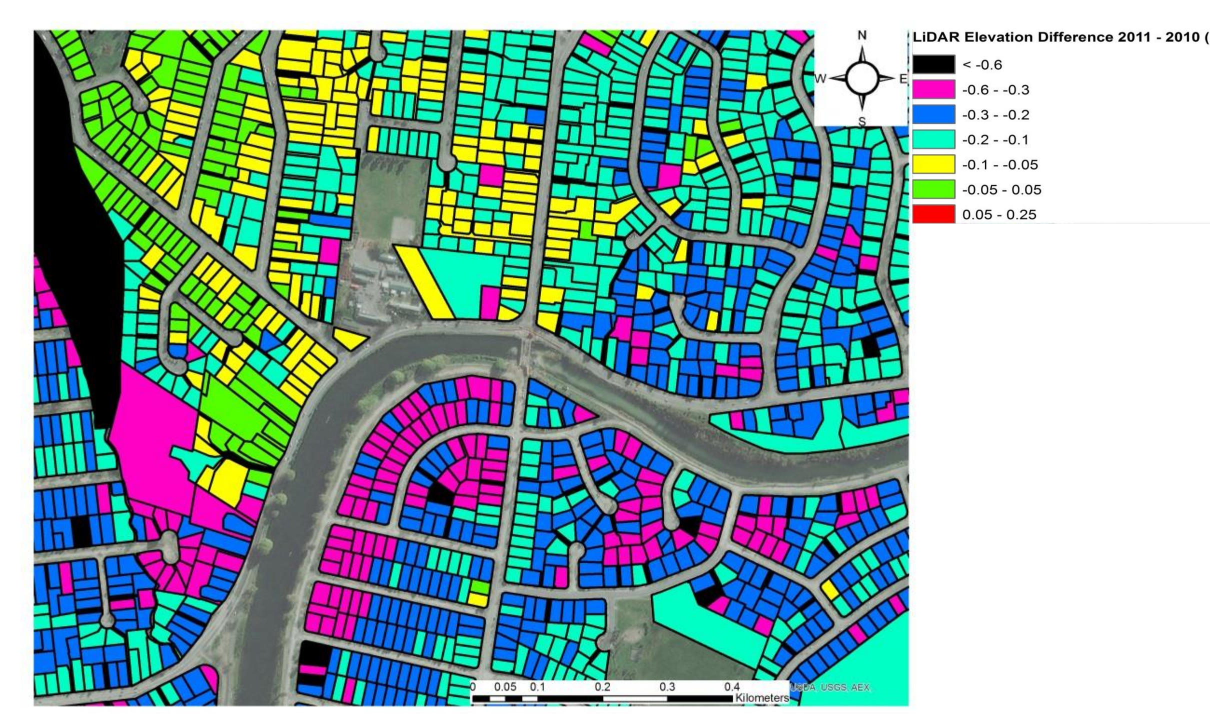

Figure 6. Average Lidar-calculated settlement for each property - close up scale

Figure 7. Maximum Lidar-calculated settlement for each property - close up scale

Results

- The Lidar data is correlated with field observation of liquefaction.
- As the degree of severity increases, the value of Lidar-calculated settlement also increases and vice versa.
- There is a huge difference between considering Min, Max or the average value of the Lidar as the final settlement value of each property.

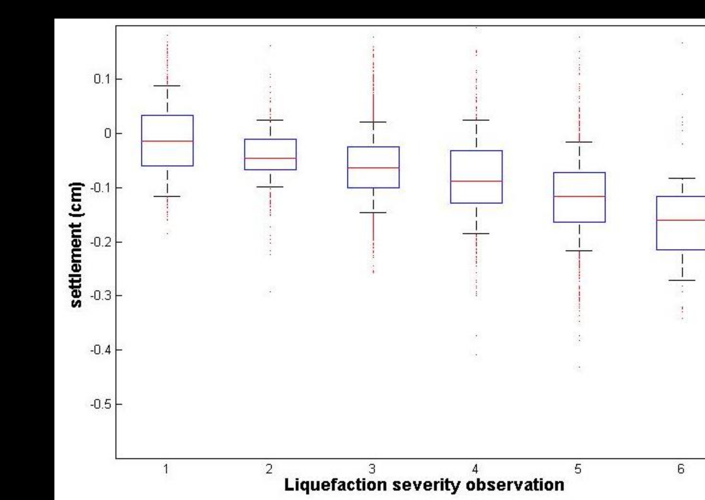

Figure 8. Correlation between the field severity observation and Minimum Lidar-calculated settlement

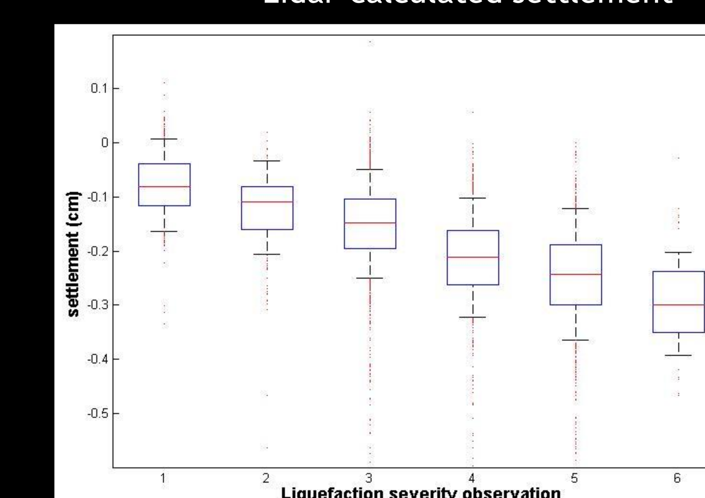

Figure 9. Correlation between the field severity observation and Average Lidar-calculated settlement

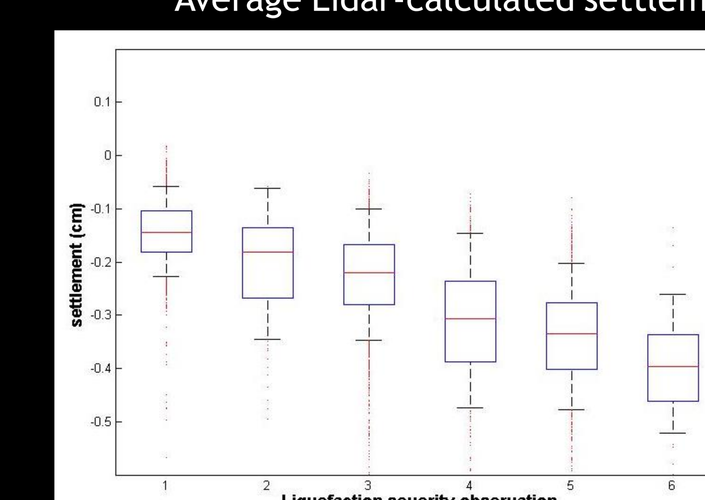

Figure 10. Correlation between the field severity observation and Maximum Lidar-calculated settlement

Reference

Ishihara, K., and Yoshimine, M. 1992. Evaluation of settlements in sand deposits following liquefaction during earthquakes. *Soils and Foundations*, 32(1):173-188.

Tsukamoto, Y; Ishihara, K; Sawada, S. (2004). "Settlement of silty sand deposits following liquefaction during earthquake. *Soils and Foundations*, 44 (5), 135-148.