Evaluation of Liquefaction Potential Index (LPI) for Assessing Liquefaction Hazard: A Case Study in Christchurch, New Zealand

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BACKGROUND

• Soil liquefaction is responsible for tremendous damage to civil infrastructure. Its effects were vividly displayed during the 2010-2011 Canterbury, New Zealand earthquake sequence, which caused widespread and severe liquefaction throughout the city of Christchurch.

DATA AND METHODOLOGY

Facilitated by records from a dense network of strong-motion stations, extensive in-situ soil characterization data, and detailed documentation of liquefaction severity, the Canterbury earthquakes present a truly unique opportunity to improve our understanding of liquefaction hazards.

1. **Overview of Canterbury earthquake sequence**
   - 4 Sept 2010 Mw 7.1 Darfield earthquake
   - 22 Feb 2011 Mw 6.2 Christchurch earthquake
   - 11 other Mw ≥ 5.0 events

2. **CPT Soundings**
   - 1,495 CPT soundings performed in Christchurch region
   - Anselin Local Morans I analysis used to remove 322 soundings prematurely terminating on shallow gravels

3. **Liquefaction Severity**
   - Characterized at each CPT site following both the Darfield and Christchurch earthquakes using ground reconnaissance, high-resolution satellite imagery, and lateral spread measurements.

4. **Conditional Peak Ground Accelerations (PGAs)**
   - Using more than 20 near-source strong-motion station recordings, the Bradley (2010) GMPE, and the spatial correlation model of Goda & Hong (2008), conditional PGA distributions were computed from:
     \[ [\ln \text{PGA}_{\text{Darfield}}] = X [\ln \text{PGA}_{\text{Christchurch}}] + \beta + \rho \cdot \text{PGA}_{\text{Darfield}} \cdot \text{PGA}_{\text{Christchurch}} \]

5. **Liquefaction Evaluation and LPI**
   - FS₈₅ computed from Robertson and Wride (1998)
   - LPI computed as per Iwasaki et al. (1978)

RESULTS AND DISCUSSION

1. **Prediction of Liquefaction Occurrence** (2346 Cases)
   - Ground-water fluctuation and uncertainty of PGAs were among factors resolved to be unlikely cause of errors.
   - Trend identified between liquefaction over-predictions and plasticity of soil in capping and/or interbedded non-liquefied layers; further research is needed to better understand and quantify these effects.

CONCLUSIONS

1. LPI and Iwasaki criterion generally effective in predicting damaging liquefaction; should be used with caution in locations susceptible to lateral spreading.
2. Liquefaction probability better than threshold LPI values.
3. LPI could be improved by accounting for characteristics of soils in both layers predicted to liquefy and the crust and/or interbedded layers predicted not to liquefy.