# Assessing vulnerabilities in Beirut Post-Explosion: combing survey and satellite data

Elisabetta Pietrostefani[1]

[1]Department of Geography and Planning, University of Liverpool

GISRUK 2023

**Summary**

On the 4th of August 2020, a large amount of ammonium nitrate stored at the port of the city of Beirut exploded causing at least 200 deaths and over 7,000 injuries. This research builds on spatial survey data together with satellite imagery measuring the degree of damage of buildings to investigate the changing landscape of local vulnerabilities before and after the explosion. This original data is based on surveys conducted in 2018 and 2021 for representative samples of two Beirut neighbourhoods. The research evaluates alterations in vulnerability indicators (livelihoods, housing, and mental-wellbeing measures) and focuses on the added-values of combining satellite imagery with perception-based surveys to further the understanding of urban inequalities.

**KEYWORDS:** vulnerability; satellite data, post-disaster, survey, urban inequalities

## 1. Short introduction

On the 4th of August 2020, a large amount of ammonium nitrate stored at the port of the city of Beirut exploded, causing at least 200 deaths, over 7,000 injuries, US$3.8-4.6 billion in material damages, and the displacement of over 300,000 people. Lebanon was already suffering from a rapidly escalating financial crisis, further aggravated by the outbreak of COVID-19. This paper spatially explores survey data collected in 2018 and 2021 in Beirut, together with satellite imagery measuring the degree of damage of buildings. These datasets are exploited to investigate the changing landscape of local vulnerabilities from pre-crisis to post-explosion. The term 'pre-crisis' marks the period before the Lebanese liquidity crisis which started in August 2019. The term 'post-explosion' marks the period after the 4th of August 2020 port explosion. This original data is based on four survey datasets conducted between 2018 and 2021 for representative samples of the comprehensive population count of areas of Ras Beirut and Mar Mikhael, two neighbourhood of Beirut, proportionally stratified by nationality (Lebanese and non-Lebanese).

Lebanon is no stranger to post-disaster reconstruction. The Beirut city centre reconstruction after the Lebanese Civil War is a closely tied example of the renovation of a historic core, though it displaced its local populations and dismantled entire neighbourhoods to make way for luxury developments (Davie, 2004; Verdeil, 2002). This not-so-distant episode created an underlining threat to the welfare and security of vulnerable residents in neighbourhoods adjacent to the Beirut port area, many of which were displaced following the blast and had not returned one year after the explosion. Keeping this in mind, as well as the conspicuous alterations that many Beirut neighbourhoods have undergone over the past few decades (Gebara et al., 2016), this paper builds on Pietrostefani et al.'s (2022) analysis of livelihoods, housing and mental-wellbeing and focuses on the added-values of combining satellite imagery with perception-based surveys to further understanding of urban inequalities.

## 2. Data

The assessment of the buildings damage in Beirut after the blast relies on three research projects conducted in the area: ARIA/NASA, the Reform and Recovery and Reconstruction Framework (3RF) and the FER dataset.

We aggregate the NASA data RGB bands made into one grey band:

$$L = R \times \frac{299}{100} + G \times \frac{587}{1000} + B \times \frac{114}{1000} \quad (1)$$

**Figure 1** illustrates a visualisation of this classification. We vectorized the transformed raster NASA dataset and spatially joined with the Beirut building dataset. We then calculated the average value of the composite band grouped by each building. We join the dataset with the buildings classified by NASA with the 3RF and FER datasets. Finally, based on the statistical distribution of the values, existing building classifications in both 3RF and FER dataset and visual inspection, we classified the NASA data into four groups (‘Severe Damage’, ‘Moderate Damage’, ‘Minor Damage’, ‘No Damage’). We also leveraged the 3RF data source to correctly reclassify the buildings destroyed by the blast into a ‘Destroyed’ category. Based on both the 3RF and FER dataset, we also identified buildings under reconstruction and new buildings at the time of the research, creating two additional categories.


**Figure 1** Survey assessment of structural damage of buildings.

This original survey data is based on six survey datasets conducted between 2018 and 2021. All these surveys were collected by citizen scientists, who were an integral part of the data collection and initial stages of analysis. The household surveys were conducted for representative samples of the comprehensive population count of areas Ras Beirut and Mar Mikhael. The sample size for non-Lebanese is calculated using the same formula, but by applying a finite population correction factor that accounts for the smaller population size of non-Lebanese within the area. The sample size was calculated using a 95 percent level of confidence (Z=1.96), and a 5 percent margin of error, and an estimated average household size of 3.4 for Lebanese (CAS & ILO, 2020) and 4.7 for Syrians (UNHCR et al., 2020). The blue lines in **Figure 2** illustrate the points in time of the different surveys in relation to the Beirut Blast and other shocks.

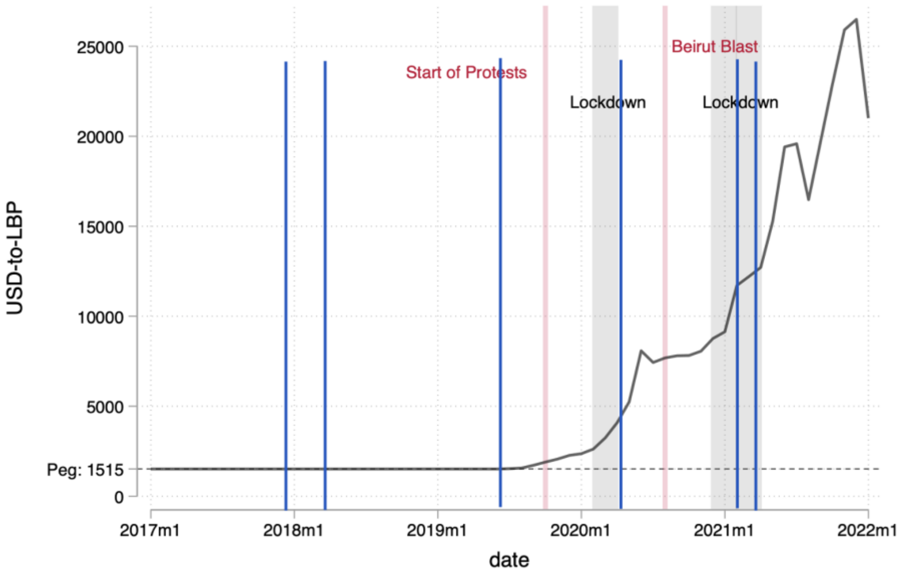


**Figure 2** Survey datasets timeline in relation to Beirut Blast and other shocks

## 3. Methodology

This research builds on the work that the Institute for Global Prosperity (IGP) – RELIEF centre has been conducting in Lebanon over the past three years (Mintchev et al., 2019; RELIEF Centre & UN-Habitat Lebanon, 2020). It also expands on the Participatory Spatial Intervention developed as part of the research project 'Public services and vulnerabilities in the Lebanese context of large-scale displacement' (Dabaj et al., 2020). The research further contributes to humanitarian agencies' tracking of vulnerabilities in the Lebanese context (UNHCR et al., 2020), and to the literature on citizen science and sustainable development goals (Fraisl et al., 2020).

We adopt three methodological strategies. In the first instance classification techniques to identify urban morphological changes from the Beirut blast using classification techniques, and a first-difference approach to evaluate the effects of the blast. The first-difference approach exploits original survey data from both Beirut neighbourhoods to explore differences in livelihood and well-being effects. The difference-in-difference approach exploits the survey data from both Mar Mikhael (treated) and Ras Beirut (control) to show that although the blast's livelihood indicators have been more negatively affected in areas of Beirut, mental health and subjective well-being indicators have been similarly affected across sites. An advanced tree-based regression model (LightGBM) is then designated to predict the relationship between morphological indices and vulnerability indicators. This final strategy is adopted to test the predictive potential of remotely sensed data to assess vulnerability and inequality indicators following both human related disasters.

This work contributes to expanding the toolkit of urban morphology studies adopting quantitative techniques to evaluate disasters through spatial data collection on the ground. It underlines the importance of open-source GIS software and processing scripts in post-disaster contexts needing recovery solutions, and the capitalisation of satellite data in data-poor contexts.

## 4. Acknowledgements

Thank you to the funders for their support in the different phases of research. The UKRI Global Challenges Research Fund via the project 'Assessing Vulnerabilities for urban recovery solutions in Beirut Post-Explosion' and the Economic and Social Research Council via the RELIEF Centre (Grant ES/P008003/1). The Geography and Environment Department at the London School of Economics for Seed Funding (2022) that allowed to further analysis of this research. We also thank the Institute for

Global Prosperity (IGP) – RELIEF centre and the Beirut Urban Lab for use of survey data.

## References

CAS, & ILO. (2020). *Labour Force and Household Living Conditions Survey 2018-2019*. Beirut.

Dabaj, J., Rigon, A., & Baumann, H. (2020). *Participatory Spatial Intervention: How can participatory design and a diversity lens help address vulnerabilities in Bar Elias, Lebanon?* UCL & CatalyticAction, London.

Davie, M. F. (2004). *Le patrimoine architectural et urbain au Liban: prise de conscience, idéologies de protection et éléments de prospective*. Beirut.

Fraisl, D., Campbell, J., See, L., Wehn, U., Wardlaw, J., Gold, M., Moorthy, I., Arias, R., Piera, J., Oliver, J. L., Masó, J., Penker, M., & Fritz, S. (2020). Mapping citizen science contributions to the UN sustainable development goals. *Sustainability Science*, *1*, 3.

Gebara, H., Khechen, M., & Marot, B. (2016). *Mapping New Constructions in Beirut (2000-2013)*. Jadaliyya. http://www.jadaliyya.com/Details/33751/Mapping-New-Constructions-in-Beirut-2000-2013

Mintchev, N., Baumann, H., Moore, H. L., Rigon, A., & Dabaj, J. (2019). Towards a shared prosperity: co-designing solutions in Lebanon's spaces of displacement. *Journal of the British Academy*, *7*(2), 109–135.

RELIEF Centre, & UN-Habitat Lebanon. (2020). *Hamra Neighbourhood Profile*.

UNHCR, UNICEF, & WFP. (2020). *Vulnerability Assessment of Syrian Refugees in Lebanon*. UNHCR, Beirut

Verdeil, E. (2002). *Une ville et ses urbanistes: Beyrouth en reconstruction*. Université de Paris I - École doctorale de Paris Centre.

## Biography

Elisabetta Pietrostefani is a geographic data scientist interested in applying data and technologies to improve the understanding of urban development and inequalities. She has analysed the effects of density policies and urban development and assessed inequalities in contexts of mass displacement. She holds a PhD in Planning Policy and Urban Economics from the London School of Economics and is currently Lecturer in Geographic Data Science at the University of Liverpool.