Coastal Communities under Threat: Comparing Property and Social Exposure

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We examine the threat to coastal communities from sea level rise and extreme flooding. A distinction is drawn between the exposure of the physical property base of a community and its social composition. We investigate whether any correspondence exists between these two dimensions of vulnerability and whether it holds for both small and large communities. Flood scenarios along the Israeli coast are defined and we look at the resultant property and exposure patterns in communities at different flooding increments. Results are presented for three select inundation increments. Using comparative and graphic methods, we analyze exposure rankings for different communities and property and social exposure at the intra-urban level. We use break point analysis to trace the evolution of community exposure at different flooding increments. We conclude with some cautionary policy implications with respect to opportunities for change in highly exposed communities in the wake of extreme flooding.

Keywords: Exposure, sea-level rise, Israeli coast, vulnerability index, extreme flooding.

Vulnerability of coastal communities is an issue high on the agenda of urban planners, disaster management specialists and appointed public officials. 'Vulnerability' is an intangible concept that has been defined in several ways (Fussel and Klein, 2005). Socio-economic vulnerability is commonly acknowledged as encompassing both the physical-capital fabric of the community and also its social composition. Often these two dimensions are integrated to generate a composite index (Clark et al., 1998; Cutter et al., 2003; Chakraborty et al., 2005; Wood et al., 2010; Martinich et al, 2013). This homogenization, while serving operational and policy interests may however be smoke-screening subtle distinctions between property and population exposure. This paper treats them separately, grounded in the belief that they represent complementary sides of the vulnerability coin. We analyze the exposure to flood risk of both the physical-property base of coastal communities and their social base, along the Mediterranean coast of Israel. The physical-property ex-

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posure of a community reflects its wealth foundation. This is capitalized in the value of capital stock of residential properties at risk. Social exposure, which is comprised of the aggregate characteristics of the population at risk, denotes the human composition of threatened communities. Despite the tendency to assume an association between property and social exposure, there does not need to be any a-priori correlation between the two. For example, we can envisage a case of physically disabled people living in highly valuable sea-front residences or alternatively of highly skilled graduate students living in cheap accommodation in flood prone zones.

The aim of this paper is to test whether there is any correspondence between these two dimensions of exposure: are communities with high property exposure also socially vulnerable? Does this correlation hold for large and small communities? What does this mean for community resilience? The rationale for distinguishing between these two aspects is that policy implications may be very different. In coastal communities where property exposure is high but social vulnerability is low, policy prescriptions may point to in-situ coastal protections and efforts to preserve community coherence through deepening capital investment. Alternatively, in communities where social composition is highly vulnerable and property exposure is low due to low level of investment and value, policy solutions may point to more stringent regulatory practice or even relocation.

This paper proceeds as follows. In the next section we review the literature on vulnerability indices, paying special attention to proxies for property and social exposure and composite indicators of vulnerability. We then proceed to describe the method of analysis. This involves delimiting the flood increments and comparing property and social exposure for coastal local authorities at different flood levels. The data analysis that underpins this exercise is outlined in the following section and particular attention is paid to the allocation of data to buildings in order to create micro level property and exposure data. We conclude with some policy implications arising from the analysis. These caution against over-exuberant public policy experiments in highly exposed communities often under the guise of promoting community revitalization in the aftermath of extreme flooding events.

LITERATURE REVIEW

Adaptation and planning for future sea-level rise (SLR) and extreme coastal flooding (EF) is a cardinal issue for coastal management and climate change economics due to its significant future costs and inherent complexities. Different physical landscapes (i.e. coastal landforms or real estate properties) and different societal structures may require different physical and social adaptation strategies. These strategies cover a vast realm of possible pre and post event efforts and may include hard coastal protection, elevation of property, beach nourishment and coastal stabilization techniques such as vegetation stabilization. But they can also include retreat options,

evacuation management plans, personal household preparation and future development regulations (i.e. setback lines etc.). In any event, effective response necessitates a good understanding of those communities who might be disproportionately affected either because their property is highly exposed or because their relative loss is higher and therefore their ability to cope is lower.

In considering adaptation and planning strategies, the uncertainties of exposure are compounded. Uncertainties in predicting the magnitude of future SLR (Willis and Church, 2012) and to an even greater extent future EF (Woodworth and Blackman, 2004; Vilibić et al. 2012), make planning for the unknown future a precarious task. Additionally, the difficulties in projecting future resources and property value add further uncertainty (Neumann et al., 2011). Coastal management and adaptation planning may take place at different spatial scales requiring different decision support systems and varied inputs in terms of the information and analyses on which they rely. Equipping decision makers and coastal planners with comprehensive information to assist and support future adaptation is a critical step in risk analysis. This entails complex analysis of both physical property and socio-economic data. Risk is often defined either as simply the probability of occurrence of a hazard or in combination with its consequences or outcome (Brooks et al. 2005, Brouwer et al., 2007, Clark et al. 1998, Cutter 2003). Consequently, the same hazard might not yield the same consequences given a different set of conditions. Assessing the vulnerability (physical, environmental, biological, socio-economic) of a study unit helps in identifying the plausible consequences and outcomes and therefore in the assessment of the risk in the broader sense of the term.

Studies concerning property vulnerability often deal with the retreat-protect dilemma in a cost-benefit framework, weighing the costs of adaptation against the value of the properties for protection (Nicholls et al., 2008; Neumann et al., 2010, 2011). Analyses of property at risk can also help to delineate the areas where properties are located and estimate the feasibility and optimization of that protection. Nicholls et al. (2008) demonstrate that by focusing protection efforts on just small fractions of the global coastline, displacement of a large share of the coastal population can be avoided. Others deal with estimating the reduced value of properties located in a flood plain or a hazardous zone (Harrison et al., 2001; Bin et al., 2008) and the effect that EF has on property value (Bin and Polasky, 2004). The latter suggest that extreme flooding might render the population in the flooded zone even more vulnerable or at least less wealthy. Martinich et al. (2013) find that socially vulnerable communities are more likely to opt for the retreat option than costly defense strategies, since their property is of a lower value and therefore less likely to be worth protecting. This underscores that exposure is not just an issue of coastal management and planning but also of social equity and justice.

Socio-economic vulnerability assessments in turn, are not detached from physical-property considerations. They often consider individual wealth but are mostly concerned with analyzing collective resilience or adaptive capacity. Adaptive capac-

ity is a component of vulnerability which relates to the ability to adapt over time (Brooks et al. 2005, Brouwer et al., 2007). In most studies it stems from the socio-economic status of inhabitants at risk, manifested in census demographic properties, which often are captured in a composite socio-economic vulnerability index. Several indicators are typically used for social vulnerability analysis including age, disabilities, income, occupation, race, family status, housing and infrastructure and lifelines (Clark et al., 1998, Chakraborty et al., 2005). There are many ways to select social indicators in order to calculate vulnerability. Brooks et al. (2005) correlate mortality rates due to climate related disasters and socio-economic and political indicators in order to identify the relevant vulnerability indicators. Validation and weighting is incorporated using expert judgment. Clark et al. (1998), Cutter et al. (2003) and Fekete (2009) use factor analysis to simplify their multivariate data and cluster redundant variables. After choosing the relevant indicators an index is composed either by simply adding or averaging all components or by assigning weights to each component which requires subjective expert judgment. Finally, Rygel et al. (2006) utilize a Pareto ranking method in order to avoid subjective weighing by ranking each case in the data set by a composition of indicator scores in relation to other cases.

METHOD

Our approach is essentially comparative and graphic. We define flood scenarios along the Israeli coast and look at the property and exposure patterns in coastal communities at different flooding increments. We present results for three select inundation increments. These denote different flooding scenarios: 1m represents sea level rise (SLR), 2m and 5m represent extreme flooding (EF). A 10m elevation increment represents the Low Elevation Coastal Zone (LECZ). This is the entire coastal area below 10m which is hydrologically connected to the sea (McGranahan et al., 2007). It is important to note that the LECZ is not an inundation scenario per-se. Rather, it represents a spatial delineation of the area in close proximity to the coastline at low elevation that could be affected by residual impacts of inundation.

The Mediterranean coast of Israel is 195 km long. The shoreline consists of beaches that extend up to 300m in width in the vicinity of river estuaries and is backed by a 70 km long series of aeolianite ridges. The coastal plain is the most densely populated area in the country and includes two of the three major cities in Israel (Tel Aviv-Yafo and Haifa), both with large metropolitan hinterlands. Tel Aviv-Jaffa, the second largest city in the country (after Jerusalem), has a population of more than 400 thousand inhabitants. Haifa, the third largest city has a population of more than 250 thousand inhabitants. We use municipalities as the spatial unit of analysis in this study because they represent the relevant level at which planning and decision making are conducted. Out of 254 municipalities in Israel, 32 have residential

buildings within the LECZ. Large differences exist in the size of coastal municipalities along the coast. Nine of them have populations of over 100 thousand and three have less than 10 thousand inhabitants. The stages of the analysis are as follows:

Delineating the flood zones

We create inundation maps for four different elevation increments: 1, 2, 5 and 10m, representing SLR, EF and the LECZ respectively. Global SLR rose at a non-linear rate of 1-2 mm/year during the 21st century with significant accelerations (Jeverjeva et al., 2008; Church and White, 2006; 2011; Woodworth et al., 2011) and a rate of 3.2 mm/year in the last couple of decades (Church and white, 2011). Projections for the 21st century vary considerably and range from 0.2 to 2 m (Meehl et al., 2007; Rahmstorf, 2007; Pfeffer et al., 2008; Grinsted et al., 2010), but fail to provide an accurate rate (Willis and Church, 2012). Periodical flooding is estimated by considering return periods (probabilities) of extreme high tides (1m represents a return period of 1:100 years (Golik and Rosen, 1999)) and extreme events such as Tsunamis. The inundation layers serve as the platform for the exposure analysis. Each inundation increment is determined by two main factors: topography and hydrological connectivity to the sea. We use a passive inundation model where at each increment the entire area below the relevant topographic elevation which is hydrologically connected to the sea, is presumed to be flooded (see Lichter and Felsenstein, 2012).

Data Analysis

This involves two main tasks: allocating floorspace, value and inhabitants to buildings in the flood zones and creating a social vulnerability index. The former is accomplished using a detailed GIS building data layer and by disaggregating administrative statistical data available for small spatial units (statistical areas-SA's) and re-aggregating it at the level of the individual building. In this way we achieve a much more reliable spatial distribution of properties and inhabitants. Additionally, we develop a composite social vulnerability index which uses socio-economic variables with appropriate weightings for the task at hand. The mechanics of this data processing are described in the next section.

Comparison of Exposure Rankings at the Municipal Level

We rank coastal municipalities along the coast at different flood elevation levels. We do this for both absolute and relative indices of exposure. In addition we categorize property and social vulnerability into dichotomous groups (high and low) using natural break points in the data and observe the resultant exposure patterns for key coastal municipalities at the different flood zone levels. This allows us to trace the exposure progression of a given community with increasing flooding level.

Property and Social exposure at the intra-urban level

Analysis at the aggregate municipality level may smokescreen or amplify the extent of exposure correspondence that exists at the micro level such as the street, city block or urban quarter. Given the existence of buildings level data, we are able to test the possible existence of modifiable areal unit (MAUP)-type effects in exposure patterns (Openshaw, 1984; Fotheringham and Wong, 1991). The MAUP condition exists when measures of statistical association such as correlations, vary with scale. Using GIS tools, we are able to zoom-in and graphically demonstrate the levels of correspondence that might be overlooked in aggregate analysis.

DATA PROCESSING

Property exposure is manifested in residential assets exposed to risk, both in terms of floor space and in terms of monetary value. Social exposure is expressed first, by the gross number of inhabitants exposed to risk and second, by the relative socio-economic status of those exposed inhabitants using an appropriate vulnerability index. To operationalize these concepts we use GIS tools to create the following variables: residential building floor space, residential building value, exposed inhabitants, socio-economic vulnerability index.

Residential building floor space

A national polygonal building layer containing land heights and roof heights of buildings is used to calculate the floor space in m² (the total area of a building multiplied by its number of floors) for each building. The layer contains building land-use classification and for this study, we use only residential buildings. The number of floors in residential buildings is calculated by dividing building height by average floor height of 3.5m.

Property capital stock-Residential building value

This variable is derived from a house price series made available from the CARMEN data base by the Israel Tax Authority. It registers all housing transactions in nominal prices. Our data relates to a data series from 1997-2008 by statistical area. Since transactions were not registered in all statistical areas every year, we aggregate all transactions across each statistical area, and standardize all prices in terms of real 2008 values. In places where less than three annual transactions exist, coarser resolution regional-level data are used. Values per m² are multiplied by the floor space under flood in each increment.

Exposed inhabitants

We use the building layer in order to disaggregate and spatially re-distribute statistical area level population counts:

The average number of inhabitants per m² of residential floor space in a statistical area (I_{SR}) is calculated as follows:

$$I_{SR} = \frac{I_S}{S_{SR}}$$

where:
S_{SR} = Total statistical area residential floor space.
I_S = Total population per statistical area.

Population counts per building (I_B) are then calculated as follows:

$$I_B = I_{SR} \times S_{BR}$$

where:
S_{BR} = Total residential building floor space.

Socio-economic vulnerability index

We use four key social variables obtained from the national census (2008) to define social vulnerability at the spatial resolution of the statistical area. These are: average income, disabilities, age groups and number of vehicles per household.

Household income represents a direct measure of socio-economic status. Disabilities (I_d) represent the share of disabled persons in a statistical area. It combines the share of persons who are unable or have difficulty walking, hearing, seeing, have memory problems or unable to dress and shower independently. Age (I_d) portrays the size of the dependent population in the SA and combines the percentage of persons over 65 and under 18 in the statistical area. Vehicles (I_v) depicts to the percent of households in a SA with one car or more. While this can be construed as a measure of wealth it is also a measure of a capacity of evacuate in the case of an extreme event. We regard this indicator with caution since in large cities for example, it is not always an efficient indicator of wealth and some hazards (SLR for example) do not require rapid evacuation. Therefore, this indicator is assigned a weight of 0.1 in the overall index.

We divide the national distribution of each indicator into quintiles (1- least vulnerable, 5-most vulnerable) and assign each statistical area to its respective class. Following Cutter et al. (2003), we derive a weighted composite index as follows:

$$SV = I_i * 0.5 + I_d * 0.2 + I_a * 0.2 + I_v * 0.1$$

where: SV = the vulnerability index, I_i = income quintile, I_d = disability quintile, I_a = age quintile, I_v = vehicle quintile. After ascribing a vulnerability score (SV) to each SA in the country, we divide national population into quintiles in order to get the same number of persons in each vulnerability category.

RESULTS

We start by observing absolute and relative levels of property and social exposure. First, we rank communities according to their level of absolute exposure and then we report relative exposure of each community to its own property stock and population totals (i.e. percentage of exposure). In property exposure we distinguish between floor space and the value of exposed property. In certain communities, high exposure in terms of floor space does not necessarily translate into high property value exposure. At the same time, in other communities high values of exposed property do not necessarily mean high exposure in terms of residential floor space. In population exposure we analyze the gross number of inhabitants exposed to risk and then focus further only on those ranked as socio-economically vulnerable (i.e. populations categorized as "high" and "very-high" on the socio-economic vulnerability index). Finally, we integrate the four variables using break-point analysis and present a comprehensive picture of exposure at different flooding increments.

Property exposure

Residential Floor Space
Table 1 ranks the top 5 communities exposed to SLR and EF scenarios in terms of floor space at the different increments. The difference between large and small communities is apparent in absolute floor space (m²). However, when looking at the percentage of exposed property out of the total floor space, it is actually the small communities that rank highest. In relative terms, these locations bear a higher financial burden as their budgets and tax revenues relate to the size of their population. The localities of Kiryat Motzkin and Kiryat Bialik are not very vulnerable when looking at the inundation increments but have more than 90% of their residential floor space in the LECZ. Figure 1a shows cumulative floor space exposed in each increment in all 32 coastal communities. When looking at the lower increments (1 and 2m) the differences between the higher ranking communities is relatively minor. However, at the 5m level and in the entire LECZ (10m), the differences in residential floor space exposure between Tel Aviv and the rest of the coastal communities becomes significant. Tel Aviv has more than 2.5 times the residential floor space of the second ranking community (Akko). In the LECZ, Tel Aviv has more

than 4 times the residential floor space of the second and third ranking communities
(Haifa and Nahariya).

Figure 1: Exposure at different elevation levels: a. Residential floorspace, b.
Residential building value, c. Inhabitants at risk, and d. Socially
vulnerable population.
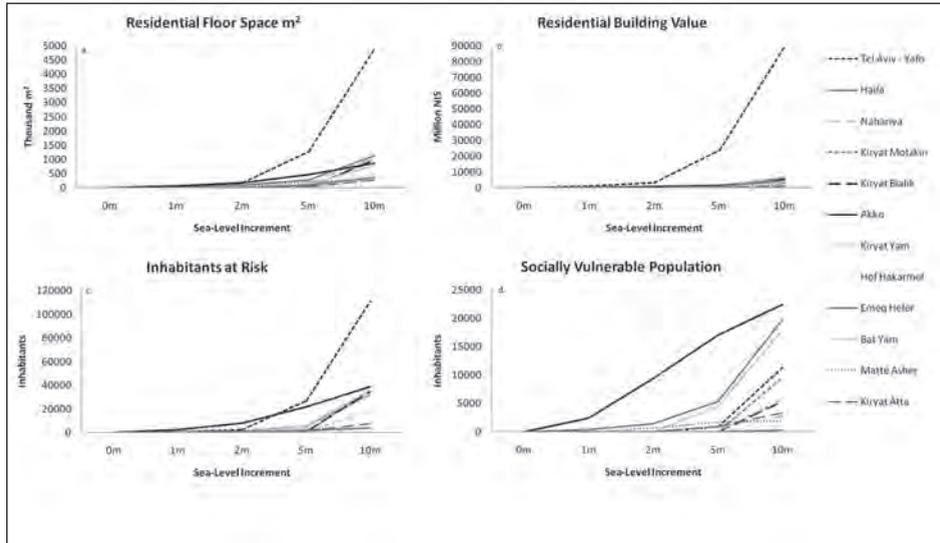
Residential building value

Here the difference between centrally located Tel Aviv and the rest of the coastal
communities is even more pronounced (Table 2). Starting at 1m, Tel Aviv has twice
the residential building value of Haifa, the second ranking community, which ac-
tually has more exposed floor space at this particular increment. In the LECZ, Tel
Aviv has more than 12 times the residential building value of the next communi-
ties (Haifa and Nahariya), indicating not only higher exposure but also the higher
value per m² in comparison with the rest of the country. Figure 1b clearly indicates
this trend showing the value of property exposure in Tel Aviv to be of a different
order of magnitude to elsewhere along the Israeli coast. When looking at relative
ranking (Table 2), smaller communities are more exposed and have a higher share
of their residential property value at risk across all inundation scenarios. Acre, for
example, ranks highest in relative terms in all inundation scenarios. When looking
at the LECZ however, other northern municipalities (Kiryat Motzkin, Kiryat Bialik,
Kiryat Yam) that are not ranked high at lower increments, have close to 90% of their
residential property value located in the LECZ.

Table 1: Municipal ranking of residential floor space at risk in different flooding increments.

Inundation Increment (m)	Residential Building Floor Space					
	Rank	Municipality	m²	Rank	Municipality	%
1	1	**Haifa**	**64,237**	1	**Akko**	**5.73**
	2	Acre	62,043	2	Matte Asher	1.56
	3	Tel Aviv-Jaffa	60,754	3	Haifa	0.77
	4	Matte Asher	31,252	4	Hof Hakarmel	0.53
	5	Hof Hakarmel	15,092	5	Tel Aviv - Yafo	0.35
2	1	**Acre**	**184,062**	1	**Akko**	**17.01**
	2	Tel Aviv-Jaffa	174,150	2	Matte Asher	2.60
	3	Haifa	108,228	3	Haifa	1.29
	4	Matte Asher	52,023	4	Jisr Az-Zarqa	1.10
	5	Hof Hakarmel	29,168	5	Tel Aviv - Yafo	1.02
5	1	**Tel Aviv-Jaffa**	**1,271,974**	1	**Akko**	**42.51**
	2	Acre	460,091	2	Kiryat Yam	11.89
	3	Haifa	270,591	3	Nahariya	10.85
	4	Matte Asher	210,441	4	Matte Asher	10.52
	5	Nahariya	163,581	5	Tel Aviv - Yafo	7.43
10 LECZ	1	**Tel Aviv-Jaffa**	**4,898,274**	1	**Kiryat Motzkin**	**94.95**
	2	Haifa	1,128,367	2	Kiryat Yam	93.64
	3	Nahariya	1,060,929	3	Kiryat Bialik	91.98
	4	Kiryat Motzkin	1,003,684	4	Akko	80.19
	5	Kiryat Bialik	977,259	5	Nahariya	70.36

Population exposure

Exposed inhabitants

Table 3 shows the number of inhabitants residing in each inundation scenario and in the LECZ and their share of the entire municipal population. In the first two increments (1 and 2m), the northern municipality of Akko is ranked the first in both absolute and relative measures. The number of exposed inhabitants in Akko at these increments is almost 3 times higher than in Tel Aviv (the second ranking municipality). The relative share of those inhabitants from the entire municipal population is even higher in Akko than in the rest of the coastal communities. In relative terms, smaller and peripheral communities rank higher than the more populated communities such as Tel Aviv and Haifa in the two lower increments. In the LECZ, Tel Aviv has the highest number of inhabitants. More than 90% of the inhabitants of the northern municipalities of Kiryat Motzkin, Kiryat Bialik and Kiryat Yam are in this category. Figure 1c shows how Akko is the most vulnerable municipality in

absolute terms in the first two inundation scenarios and Tel Aviv becomes more vulnerable (in absolute terms) in the inundation scenario of 5m and in the LECZ.

Table 2: Municipal ranking of residential capital stock at risk in different flooding increments.

Inundation Increment (m)	Residential Building Value					
	Rank	Municipality	million NIS	Rank	Municipality	%
1	1	**Tel Aviv-Jaffa**	**1,084**	1	**Akko**	**4.84**
	2	Haifa	434	2	Matte Asher	2.32
	3	Acre	199	3	Haifa	0.77
	4	Matte Asher	134	4	Tel Aviv - Yafo	0.39
	5	Hof Hakarmel	46	5	Hof Hakarmel	0.27
2	1	**Tel Aviv-Jaffa**	**3,210**	1	**Akko**	**15.99**
	2	Haifa	713	2	Matte Asher	3.94
	3	Acre	655	3	Haifa	1.26
	4	Matte Asher	228	4	Tel Aviv - Yafo	1.16
	5	Hof Hakarmel	92	5	Jisr Az-Zarqa	1.10
5	1	**Tel Aviv-Jaffa**	**23,756**	1	**Akko**	**39.44**
	2	Haifa	1,638	2	Matte Asher	13.10
	3	Acre	1,617	3	Nahariya	12.38
	4	Emeq Hefer	1,222	4	Kiryat Yam	10.02
	5	Nahariya	1,116	5	Tel Aviv - Yafo	8.60
10 LECZ	1	**Tel Aviv-Jaffa**	**89,627**	1	**Kiryat Motzkin**	**94.64**
	2	Nahariya	6,893	2	Kiryat Yam	92.24
	3	Haifa	6,404	3	Kiryat Bialik	89.62
	4	Kiryat Motzkin	5,428	4	Akko	78.66
	5	Kiryat Bialik	5,325	5	Nahariya	76.49

Exposed vulnerable population

   By looking at the socially vulnerable inhabitants rather that the total number of inhabitants at risk we highlight those communities with less coping ability in the face of an external shock. Table 4 shows the northern municipality of Akko as ranking highest in both absolute and relative terms under all scenarios. Figure 1d and Table 4 illustrate that in relative terms, Akko ranks first (far higher than all other communities) followed by Haifa and Kiryat Yam. Tel Aviv, in terms of vulnerable population exposed only appears in the LECZ ranking, where it ranks the 4th.

Table 3: Municipal ranking of inhabitants at risk in different flooding increments.

| Inundation Increment (m) | Inhabitants At Risk | | | | | |
| | Totals In Municipality | | | % Of Total Municipal Figures | | |
	Rank	Municipality	#	Rank	Municipality	%
	1	**Acre**	**2,420**	1	**Akko**	**5.27**
	2	Tel Aviv-Jaffa	748	2	Matte Asher	1.82
1	3	Matte Asher	401	3	Hof Hakarmel	0.38
	4	Haifa	398	4	Tel Aviv - Yafo	0.19
	5	Bat Yam	193	5	Emeq Hefer	0.16
	1	**Acre**	**7,791**	1	**Akko**	**16.97**
	2	Tel Aviv-Jaffa	2,512	2	Matte Asher	3.03
2	3	Haifa	1,308	3	Jisr Az-Zarqa	1.31
	4	Matte Asher	666	4	Emeq Hefer	0.91
	5	Emeq Hefer	318	5	Hof Hakarmel	0.86
	1	**Tel Aviv-Jaffa**	**26,754**	1	**Akko**	**47.57**
	2	Acre	21,833	2	Kiryat Yam	15.10
5	3	Kiryat Yam	5,707	3	Matte Asher	13.40
	4	Haifa	5,584	4	Nahariya	9.64
	5	Nahariya	4,947	5	Tel Aviv - Yafo	6.63
	1	**Tel Aviv-Jaffa**	**111,187**	1	**Kiryat Motzkin**	**95.51**
	2	Acre	38,678	2	Kiryat Yam	94.91
10	3	Kiryat Motzkin	36,676	3	Kiryat Bialik	92.73
	4	Kiryat Yam	35,877	4	Akko	84.27
	5	Kiryat Bialik	34,495	5	Nahariya	63.45

Break-point analysis

Figure 2 presents a comprehensive analysis of selected coastal communities where each community is categorized on the basis of a dichotomous high/low categorization relating to the four variables used in this study: two property exposure variables and the two social exposure variables. This is done for each increment separately such that each community can have a different level and type of vulnerability under each inundation scenario and in the LECZ. The category classification is based on identifying natural breaks in the data. In this way communities are categorized relative to others.

The top part of each divided circle represents property vulnerability: the left quadrant (M) signifies floor space vulnerability and the right quadrant (V) represents property value (all in absolute terms). The bottom half of each circle represents vulnerability of residents in absolute terms with (P) denoting total inhabitants exposed and (S) signifying socio-economically vulnerable of population at risk. Dark gray denotes high and light gray denotes low vulnerability. Only select municipalities are shown in Figure 2. As the inundation increment increases an increasing number of

municipalities become categorized as highly vulnerable. Due to the relative nature of the comparison, it is feasible for a given community to be categorized as highly vulnerable for a certain variable at a low increment and at a higher increment to be categorized at a lower level of vulnerability for the same indicator.

Table 4: Municipal ranking of socially vulnerable inhabitants (high + very high vulnerability categories) at risk in different flooding increments.

Inundation Increment (m)		Vulnerable Inhabitants At Risk (Vulnerability Categories High + Very High)				
		Totals In Municipality		% Of Total Municipal Figures (total inhabitants)		
	Rank	Municipality	#	Rank	Municipality	%
	1	**Acre**	**2,371**	1	**Akko**	**5.17**
	2	Haifa	351	2	Haifa	0.13
1	3	Bat Yam	21	3	Bat Yam	0.02
	4	Nahariya	7	4	Nahariya	0.01
	5	Ashqelon	4	5	Ashqelon	0.01
	1	**Acre**	**6,963**	1	**Akko**	**15.16**
	2	Haifa	1,197	2	Jisr Az-Zarqa	1.30
2	3	Jisr Az-Zarqa	157	3	Haifa	0.45
	4	Nahariya	56	4	Nahariya	0.11
	5	Bat Yam	30	5	Hof Hakarmel	0.04
	1	**Acre**	**17,056**	1	**Akko**	**37.16**
	2	Haifa	5,382	2	Kiryat Yam	11.97
5	3	Kiryat Yam	4,523	3	Matte Asher	7.66
	4	Matte Asher	1,686	4	Jisr Az-Zarqa	5.66
	5	Kiryat Atta	985	5	Haifa	2.03
	1	**Acre**	**22,450**	1	**Akko**	**48.91**
	2	Haifa	19,708	2	Kiryat Yam	47.35
10	3	Kiryat Yam	17,898	3	Kiryat Motzkin	25.02
	4	Tel Aviv-Jaffa	11,333	4	Jisr Az-Zarqa	20.34
	5	Kiryat Motzkin	9,607	5	Kiryat Bialik	14.40

For example, the city of Bat Yam south of Tel Aviv is scored high in terms of property value exposure at the 1m and 2m levels but low at the 5m increment. Tel Aviv is categorized as having low socio-economic exposure in the first two flood increments and as highly vulnerable for the other three variables. Nahariya also tends to demonstrate low socio-economic vulnerability (except at the 5m increment). At the 1m level it has high exposure in terms of property value while the other variables show low level vulnerability, indicating a relatively wealthy community. Neighboring Akko, on the other hand, is highly vulnerable in every variable and at

every increment indicating first, high exposure and second, a relatively poor community. Other communities such as Kiryat Motzkin are not at all exposed to any of the three inundation scenarios, but when looking at the entire LECZ the measure of exposure is higher than 90% for almost any given indicator.

Figure 3 captures a 3D view of a small part of the southern coastal strip of Tel Aviv-Yafo, looking east from the Mediterranean. It focuses on the Yafo port vicinity and its urban hinterland that encompasses parts of south Tel Aviv. Maps for the four variables are presented at the micro (building) level. At this scale of analysis, the heterogeneity of these variables along the Tel Aviv-Yafo coastline becomes readily apparent. The spatial distribution of property value exposure seems to be correlated with the distribution of socially vulnerable populations. The cluster of socially resilient residents in high value, excluding gated communities around the Yafo port area, can be easily identified as can the lower property value neighborhoods with socially vulnerable residents as the zoom moves due east. This highlights the important issue of scale that can be lost at the aggregate level of the municipality. While Figure 2 gives a comprehensive picture of exposure at different levels, important micro level variation is typically ironed out. These MAUP- type effects are captured here graphically. For policy making at the intra-urban level, these differences can be critical.

Figure 2: Break-point analysis in selected municipalities
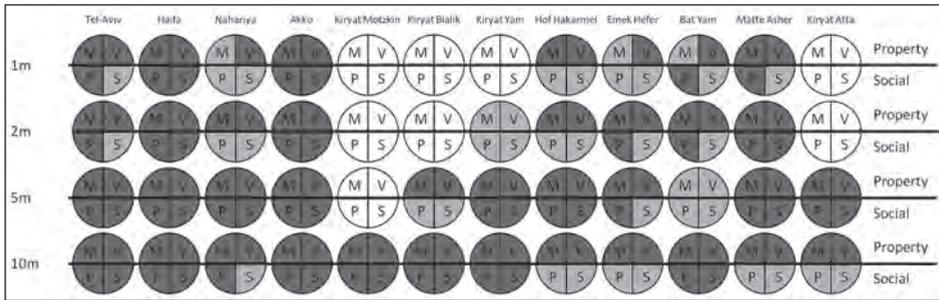
Note: Top part represents property vulnerability: M- floor space vulnerability V- property value (in absolute terms). Bottom part represents societal vulnerability: P - total inhabitants S - composite index vulnerability. Dark grey denotes high and light gray low vulnerability.

Figure 3: Spatial heterogeneity of property and social vulnerability in southern Tel Aviv and Yafo
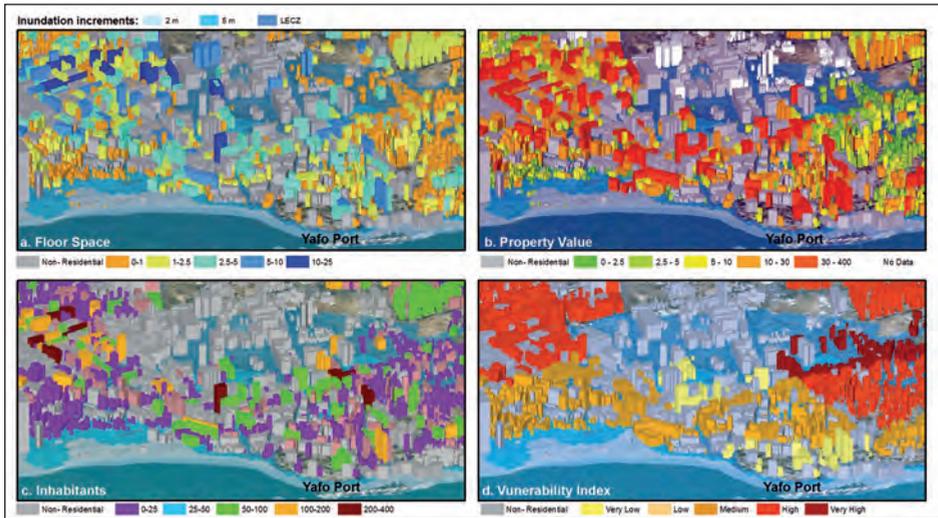
CONCLUSIONS

This study illustrates the correspondence between social and property exposure. Obviously this relationship is mediated by city size. The juxtaposition of the exposure of a large city such as Tel Aviv with small communities such as Akko, Kiryat Motzkin or Kiryat Yam, underscores this point. This is borne out in Figure 1 where Tel Aviv dominates absolute exposure across all variables aside from social vulnerability, while Akko dominates the latter in both absolute and relative terms (and other variables in terms of relative exposure). Thus, in relative terms, and this is what matters at the local level, Akko is far more exposed.

What does this mean for community resilience? Perhaps the most salient policy issue relates to adaptation and coping ability. A given magnitude of flooding damage in a small community has very different implications to the same magnitude in a large community. While the value and extent of damage may be identical, extreme inundation in a small place is not just an issue of physical loss. Local institutions, networks and relationships may be uprooted and hard to recreate. A one-time shock in a small community offers opportunities for 'time compression' processes (Olshansky et al., 2012). These refer to the attempts to compress activities such as the physical renewal or demolition of capital stock, rebuilding or restructuring of social and governmental institutions and rejuvenating land use over a short period of time due to the 'window of opportunity' generated by the unanticipated event.

These steps are much harder to implement in larger communities where infrastructure and institutions are much more cumbersome and less malleable.

In terms of policy implications, this suggests that highly exposed small communities may be subject to more speculative adaptation and mediation programs to foster recovery, than larger communities. Small communities can unwittingly become the playing field for experimental public policy measures and adaptation measures. The history of public policy in local economic development is littered with examples of vulnerable communities subjected to failed programs (Peters and Fisher 2001). Consequently, places that a priori are more exposed in terms of both their property and social vulnerability are likely to have their risk compounded by the 'opportunity for change' generated by SLR and EF. Even if the extent of damage is only moderate in absolute terms, it is the individual and community coping response that effectively determines its magnitude. In those (small) communities where both social and property exposure coalesce, public policy needs to be sensitive of the pitfalls related to such 'windows' for public sector opportunism. They may turn out to be one-way portholes instead.

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