1 **How to interpret disproportionate loss and damage from climate change? An example from**
2 **Hurricane Michael and housing impacts on Florida's Forgotten Coast**

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11 **Abstract**

12 Loss and Damage (L&D) has gained increasing attention as the "third pillar" of climate change research
13 and policy, alongside mitigation and adaptation. However, the L&D research and policy community has
14 not reached any consensus on the kinds of impacts that constitute loss and damage, whom is most
15 affected, and where, so empirical research supporting L&D is urgently required. We provide the first
16 comparative assessment of two contrasting theoretical approaches to L&D: capital theory and the
17 capabilities approach. Our analysis of residential property value and housing capability losses caused by
18 Hurricane Michael in Gulf County, Florida, reveals that the theory underpinning how L&D is approached
19 greatly affects the assessment of whom and where are most impacted. Net monetary losses of
20 residential property value totaled more than $250 million in Gulf County, and evaluation under capital
21 theory highlighted Cape San Blas and St. Joe Beach as most impacted areas, associated with higher value
22 properties and consequently high monetary losses. In contrast, the capabilities approach revealed 17%
23 of housing units were lost and high proportional value losses left many residents in sub-optimal housing
24 conditions, with North port St. Joe, Highland View, and Wewahitchka emerging as highly impacted areas
25 under this approach. The policy response to L&D from climate disasters, whether anthropogenic or not,
26 is also affected by the theoretical foundation, and we argue that the capabilities approach provides a
27 more comprehensive and effective framework to address L&D than does capital theory.

28

29 **Keywords**

30 Climate change; loss and damage; disaster response; risk management; environmental justice

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33   **1. Introduction**

34   Loss and damage from climate change—a term that describes both the UNFCCC policy arena of "Loss and
35   Damage" as well as the actual impacts that occur as a result of insufficient adaptation (i.e., "losses and
36   damages") (Otto et al., 2020)—has gained increasing attention as the "third pillar" of climate-related
37   research and policy (Mechler et al., 2019). However, the kinds of impacts considered relevant to loss and
38   damage policy and practice (e.g., economic vs. non-economic, tangible vs. intangible), and at what scale,
39   are not at all obvious. The way evidence of impacts are interpreted by researchers and policy makers will
40   have huge implications for where and who is considered "most impacted", and thus for what is
41   considered a reasonable policy response to address loss and damage when it does occur (Thomas et al.,
42   2020). Unravelling the implications of different interpretations of impacts is increasingly urgent as the
43   evidence mounts that anthropogenic climate change is already causing tangible and intangible harms in
44   different places around the world (IPCC, 2018; Tschakert et al., 2019). This urgency was most recently
45   echoed in the outcomes of the 2019 review of the Warsaw International Mechanism at COP 25 in
46   Madrid, where the committee explicitly invited parties to promote coherence in loss and damage
47   research and policy circles in order to move towards implementation of effective actions to avoid,
48   minimize or address loss and damage around the world (decision point 14; UNFCCC, 2020).

49   Multiple approaches to assessing and addressing loss and damage are available to researchers and
50   practitioners, each with a unique set of core concepts, evaluative criteria, informational requirements
51   and related policy prescriptions (Boda et al., under review-b; McNamara & Jackson, 2019). Two of the
52   main approaches include: 1) Capital Theory, a utilitarian economic theory that prioritizes maintaining a
53   society's aggregate capital stocks; and 2) the capabilities approach to Human Development, a non-
54   utilitarian welfare theory that prioritizes improving the substantive freedom (i.e. capabilities) available to
55   individuals in society, starting with the least well off. While clear differences exist in how these
56   theoretical entry points conceptualize, measure and seek to address loss and damage, the implications
57   of adopting one approach or another have not been empirically researched, and thus policy makers lack
58   concrete evidence when deciding how to consistently interpret loss and damage information and
59   translate it into effective policy.

60   We here empirically assess the impacts of Hurricane Michael to Gulf County's (Florida, USA) residential
61   properties through three different analytical lenses. These lenses include 1) total residential property
62   value losses, an indication of the *quantity* of monetary impacts; 2) proportional residential property
63   value losses, an indication of the *severity* of the impacts to a given property; and 3) loss of residential
64   units or newly vacant residential properties, an indication of the loss of housing *capabilities*. We apply
65   the three lenses to parcel-level property data collected by the Florida Tax Authority and interpret the
66   results from the contrasting capital theory and capabilities approaches to loss and damage. We discuss
67   how these competing perspectives lead to different appraisals of what defines a "highly impacted" area,
68   as well as implying very different forms of policy response.

69   We justify a focus on housing for three main reasons. First, research has consistently shown that damage
70   to housing is both a common and deeply significant impact occurring as a result of tropical cyclones and
71   other natural disasters (Comerio, 1997; Zhang & Peacock, 2009). Second, in the context of the United
72   States, housing is commonly a major source of wealth for many households, and losses in its value can

73   have significant implications for household financial security, even inter-generationally (Wolff, 2016).
74   Finally, having access to adequate housing (e.g. tenure, income status and dwelling conditions) is a
75   crucial conversion factor for many other essential social functionings, including securing income-
76   generating employment and maintaining physical and mental health (Park & Seo, 2020; Winston &
77   Pareja Eastaway, 2008). Indeed, the question of adequate and affordable housing is widely viewed as
78   central to managing future climate risks (e.g., Sajjad et al., 2020), recognizing that the housing question,
79   particularly in developing countries, will interact with and be exacerbated by increasing climate hazards
80   (e.g. heat waves, tropical cyclones), generally impacting the least-well-off most severely (IPCC, 2018).
81   Understanding how limit-breaching storms like Hurricane Michael impact housing, and what this
82   suggests about policies aimed at avoiding losses and damages, will only become more urgent in the
83   future.

84   **2. Theories of loss and damage from climate change**

85   Loss and damage from climate change are generally considered to be those impacts that occur as a result
86   of insufficient adaptation. What exactly counts as loss and damage, and how to measure it, however,
87   remain largely open questions. The outcomes of the 2019 review of the Warsaw International
88   Mechanism at COP 25 in Madrid confirmed the urgent need for clarity in loss and damage research and
89   policy circles in order to move towards implementation of effective actions to avoid, minimize or address
90   loss and damage (UNFCCC, 2020). We have argued elsewhere that loss and damage is best
91   conceptualized as the result of a cascade of failures to maintain a sustainable development, which we
92   understand to mean the *strategy* for balancing tradeoffs between imperatives of economic development
93   and environmental conservation (Boda et al., under review-a). From this perspective, we have suggested
94   that there are two internally coherent yet competing approaches to conceptualizing loss and damage in
95   terms of sustainable development, namely the capital theory approach and the human development
96   (i.e., capabilities) approach.

97   Capital theory approaches sustainable development from a utilitarian perspective and aims to sustain
98   aggregate utility over time, generally indicated by the level of per capita income. It thus emphasizes that
99   sustainable development is development that maintains a society's aggregate productive capacity (i.e.,
100 stock of productive capital), as this is considered the driver of economic growth. Monetary metrics and
101 cost-benefit analysis are tools used to monitor and evaluate capital growth over time. From this
102 perspective, housing is understood primarily as a "stock of capital" that can be invested in or divested
103 from depending on the rate of return on investment. Housing stock in this view is substitutable with
104 other productive industries, and investing in housing stock is considered economically rational when it
105 leads to growth in overall economic production (e.g., GDP). It should be noted that, while capital theory
106 is not concerned with the precise distribution of wealth in society, it is not completely negligent of the
107 issue; rather, it relies on the assumption that a well-functioning market economy will provide the most
108 efficient (and least coercive) mechanism for distributing aggregate social wealth within society.

109 The capabilities approach to Human Development, on the other hand, approaches sustainable
110 development from a non-utilitarian position, focusing on addressing objective deprivations rather than
111 solely on subjective utility. Development is thus viewed as the process by which individuals are made
112 free to pursue lives they have reason to value, rather than as the process of capital accumulation. The

113   freedom of individuals to live meaningful lives is a factor of a person's capability set, that is, the
114   substantive opportunities available to the person. Free persons can combine their different capabilities
115   to achieve different functioning states (i.e., different lifestyles). Sustainable development is thus
116   development that expands people's substantive opportunities (capabilities) to live valuable lives, and it
117   draws on a wide variety of informational sources to monitor and evaluate this process of capability
118   expansion. From this perspective, housing is understood primarily as a basic capability (i.e., the ability to
119   acquire adequate shelter) that is necessary for a wide variety of other functionings, including maintaining
120   health and employment. In this view, adequate housing is an essential service that must be provided
121   regardless of the rate of return on investment, since it provides the foundation from which many other
122   socially significant activities become possible. Others have argued that there are several purported
123   benefits to taking a capabilities approach to disaster impact studies, chief among them the
124   *disaggregation* of impacts (Gardoni & Murphy, 2009).

125   Our own previous comprehensive and systematic review of 145 loss and damage peer-reviewed articles
126   showed that, while the human development approach allows for a more diverse conceptualization of
127   what loss and damage can entail (i.e. the economic, environmental and social dimensions), the capital
128   theory approach is currently by-far the most dominant (Boda et al., under review-b; see also McNamara
129   & Jackson, 2019). Our current study provides the first direct comparison between these two approaches
130   in terms of how they interpret and measure loss and damage. Doing so helps clarify what each approach
131   sheds light on, and what is left in the dark.

3. Materials and methods

3.1. Hurricane Michael

134   The scale and type of impacts seen in the wake of Hurricane Michael, which made landfall in the Florida
135   Panhandle on October 10, 2018, in many ways represent what the best science available suggests will be
136   increasingly likely in a warmer world (IPCC, 2018). Hurricane Michael was historic in many ways. It was
137   the first category 5 hurricane to make landfall in the United States since Hurricane Andrew in 1992, and
138   only the fourth in recorded history. As the strongest storm of the 2018 hurricane season, the strongest
139   ever to make landfall in October, and the only category 5 storm on record to ever make landfall along
140   Florida's panhandle coast, Michael caused unprecedented devastation to urban settlements, agricultural
141   fields and timber resources (Avila, 2019). More than a year and a half later, many communities impacted
142   by the storm are only beginning the process of long-term recovery. Many communities along this
143   "forgotten coast", as it is locally known, were completely devastated, with housing in particular being a
144   persistent and widespread problem for citizens and local governments in the aftermath of the storm.

145   Hurricane Michael was registered as a "billion dollar" disaster according to the National Center for
146   Environmental Information, with $25.5 billion in damages and 49 deaths recorded (NOAA, n.d.).
147   Similarly, the Em-Dat database registered the storm as causing 45 deaths, with 5000 people affected and
148    $16 billion in damages, $10 billion of which was insured.

149   However, the distribution of these affects was highly uneven. Large portions of the total damage
150   amounts came from agricultural and forestry impacts (FDACS, 2018). A smaller but no less significant
151   portion of these reported impacts comes from structural damages, including devastating impacts to

152 residential properties. The National Hurricane Center's final synopsis of Hurricane Michael noted that
153 Gulf County was among the three hardest hit counties in terms of structural damages, along with Bay
154 County to the west, and Jackson County to the north, with Gulf County affected the most in per capita
155 terms (Beven et al., 2018).

156 **3.2. Study area – Gulf County**

157 Gulf County is located in the Northwestern "Panhandle" region of Florida in the southeastern United
158 States (Figure 1). Gulf County is a predominantly rural county with a population of just over 13,500
159 residents. Per capita income is just over $21,000 while median household income is around $44,000.
160 Roughly, 20% of Gulf County's population lives in poverty (*U.S. Census Bureau*, n.d.).

161 **3.3. Analysis of housing impacts**

162 We assessed losses and damages to housing at multiple scales through three different lenses: 1) absolute
163 monetary losses of property value, 2) monetary losses as a proportion of property value, and 3) losses of
164 housing capabilities. We evaluated these losses at the parcel level, then analysed them at three spatial
165 scales: the county level, the census block level, and the intermediate "urban cluster" level. Parcels are
166 the smallest spatial units of land delineated in the study area (Figure 1), with more than 18,000 discrete
167 parcels in Gulf County in 2019. Census blocks are the first level of aggregation of land parcels used for
168 statistical purposes in the US (Figure 1), which in Gulf County total 2352 blocks with an average of 7.4
169 parcels per block (NB large parcels span across the boundaries of multiple blocks in some cases). Our
170 third spatial scale of analysis, the urban cluster level (Figure 1), is a grouping of census blocks around six
171 clusters of high-density residential properties. These clusters were identified using a combination of 1)
172 county zoning maps to narrow the geographic focus to residential zonings only, 2) visual identification of
173 higher density residential areas using parcel data in ArcMap, and 3) the authors pre-knowledge of Gulf
174 County and its distinct neighborhoods.
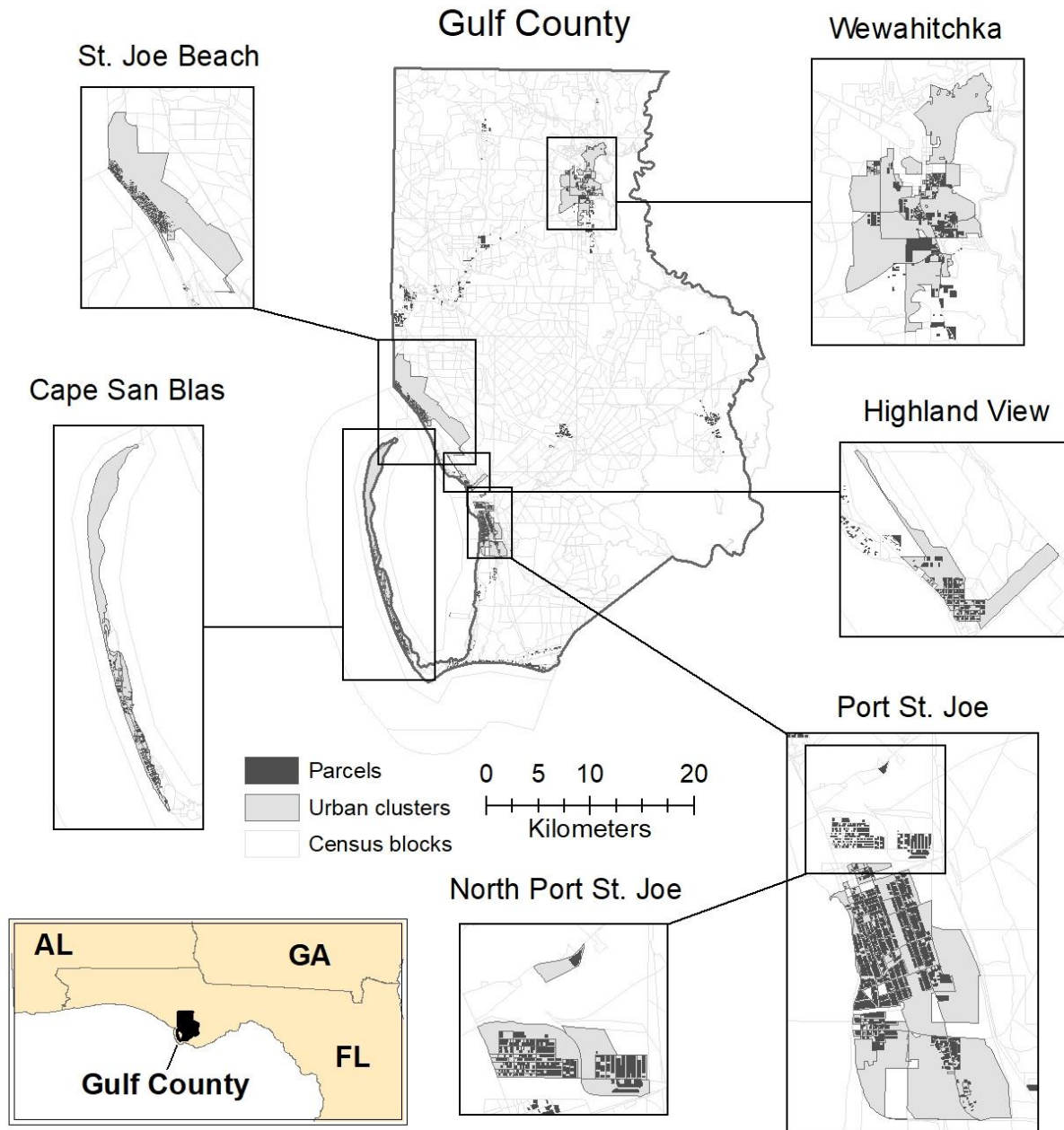
Figure 1. Spatial boundaries of Gulf County, six urban clusters analysed, census blocks, and residential parcels. Dark grey filled shapes are all 2018 residential parcels in Gulf County. Light grey borders with no fill are all census blocks in Gulf County (including those without residential parcels). Light grey filled shapes are census blocks aggregated to analyse six urban clusters, which are shown as insets. Bottom left inset shows location of Gulf County in the Florida Panhandle, USA. Note that North Port St. Joe was analysed separately from what we refer to as Port St. Joe, and what we label St. Joe Beach includes the Beacon Hill locality.

183   Housing losses were evaluated using the parcel-level property appraisal data from the Florida Tax
184   Authority. Property appraisal data for 2018 and 2019 provide records of parcel value and land use and
185   property type before and after Hurricane Michael. We confirmed with the state property appraiser that
186   a parcel-by-parcel damage assessment was conducted and recorded after the storm, and that tax
187   information contained in the property appraisal data is the most comprehensive measure of Hurricane
188   Michael impacts on housing. Though, some potential remains for under-valuing properties due to the
189   practical limitations of the valuation process (e.g., external observation vs. internal damages). The
190   property appraisal data were made spatially-explicit by joining them to the 2019 shapefile of county-
191   wide parcel boundaries.

192   We analysed all parcels in Gulf County categorized as residential in 2018. We included all parcels with
193   any of the three residential base strata used by the Tax Authority (Table 1). We used the base strata to
194   identifying the specific zoning of parcels as residential. We also observed the active strata to determine if
195   parcels were actively being used for residential purposes. We then analysed for 2019 the same parcels
196   that were categorized as residential according to their 2018 base strata, which were identified in the
197   2019 data by the unique parcel identifier. Only those parcels whose unique identifier matched between
198   the 2018 and 2019 appraisal data, as well as the 2019 shapefile, were retained. A total of 6731
199   residential parcels were analysed for the entire county, but two were removed for block- and urban
200   cluster-level analyses because of non-matching spatial data.

201   Table 1. Base strata categories of the Florida Tax Authority used to identify residential parcels in 2018.

Our category	Tax Authority Strata	Description
Residential	01	Residential property consisting of one primary living unit, including, but not limited to, single-family residences, condominiums, cooperatives, and mobile homes.
Residential	02	Retirement homes and residential property that consists of two to nine primary living units.
Residential	06	Improved commercial and industrial property (including multi-family residential with 10 units or more). Within this strata, only those parcels with 10 units or more included here.

202

203   Monetary values of all residential parcels in 2018 and 2019 were obtained from the "just value" recorded
204   in the property appraisal. We adjusted "just value" by the "just value change" also recorded in the
205   appraisal data, which reflects any adjustment made to an initial property valuation upon a subsequent
206   valuation. Monetary losses (or gains) were calculated for each parcel as the change in adjusted just value
207   from 2018 to 2019. We then calculated these parcel-level losses (or gains) as a proportion of the 2018
208   property value. One outlier was removed (parcel ID 03178-110R) whose 2018 just value change (from a
209   second 2018 appraisal) reduced the parcel value by over 95%, but the parcel's 2019 value was back to
210   within 75% of the first 2018 appraisal. These changes could not meaningfully be in interpreted in relation
211   to the storm damage, and so this parcel was removed. Finally, at the parcel level, we calculated the total

212   number of residential units lost from 2018 to 2019 as the difference in total units within all parcels
213   analysed from 2018 to 2019.

214   Next, we aggregated parcel-level assessments to the census block level. We used the 2018 TIGER/Line
215   shapefile (U.S. Census Bureau, 2018) for census blocks and the 2019 parcel boundary shapefile to
216   spatially-join parcels to census blocks. The use of 2018 census blocks was to align with demographic
217   statistical data during the year of the storm, while the use of 2019 parcels was to align with losses and
218   damages experienced after the storm. We aggregated 2018-2019 changes in property value for all
219   parcels within each block and in the total number of active residential units within each block. We then
220   excluded all blocks with a net gain in parcel value from further analyses, in order to focus on the
221   distribution of losses. A total of 463 blocks were analysed further. The magnitude of monetary and
222   housing capability losses at the block level were then compared to 2010 census data on the race, age,
223   and tenure status of householders within each block. We used 2010 census data because the 2020
224   census was incomplete at the time of analysis and no data from the various American Community
225   Surveys between 2010 and 2019 are available at the disaggregated block level.

226   We compared how housing losses from Hurricane Michael would be evaluated differently through the
227   three lenses (absolute monetary losses, proportional monetary losses, housing capability losses). We
228   analysed the rank-order of blocks according to each measure of losses because the absolute measures of
229   monetary losses are extremely skewed. In this approach, blocks with a low rank through a particular lens
230   can be considered to have sustained smaller losses when compared to a block with a high rank through
231   the same lens. If the three lenses yield similar evaluations of losses, one would expect the rank-order of
232   blocks to lie close to the 1:1 diagonal when two lenses are plotted against each other. Large deviations
233   from the expected 1:1 relationship (residuals) indicate blocks where, for example, housing capability
234   losses are much greater than monetary losses, relative to other block, or vice versa.

235   Finally, we focused on the six urban clusters (Figure 1) in order to assess intermediate-level patterns in
236   housing losses throughout the county. These include the two main cities of Port St. Joe and
237   Wewahitchka, North Port St. Joe and "St. Joe Beach" (both distinct neighborhoods within greater Port St.
238   Joe), as well as the unincorporated communities of Cape San Blas and Highland Views. These areas are
239   all zoned as residential, mixed commercial-residential or municipal. Within these zones, the clusters
240   were spatially bounded based on geographic proximity rather than formal municipal boundaries to
241   maximize the number of parcels captured in the cluster analysis. All statistical analyses were performed
242   in R and all spatial data processing performed in ArcGIS. Additional informational sources were also
243   collected to complement the primary analysis of housing data, including damage surveys conducted by
244   academic, state and private institutions.

245   In addition to our primary analysis of housing data, Boda conducted a field visit to the affected area,
246   including a purposive interview with the active director of the Citizens of Gulf County Recovery Team
247   (CGCRT), a 501 non-profit which has a mandate to help the most vulnerable citizens (e.g., low income,
248   elderly, veterans, disabled) recover. The CGCRT is the only active community-based organization working
249   for the long-term recovery of Gulf County's vulnerable residents. The interview, which lasted 45 minutes,
250   took place on March 25, 2020 in Port St. Joe, Florida. Due to the COVID-19 outbreak, the in-person
251   interview was rescheduled via telephone. The interview was not recorded; detailed notes were taken

252   during the conversation and later transcribed. Quotes from the interview that provide insight into the
253   ongoing recovery process are included where complementary to the primary quantitative analysis.

254   **4. Results**

255   **4.1. Parcel-level impacts**

256   Our analysis reveals that more than 84% of residential parcels in Gulf County sustained some degree of
257   monetary value loss between 2018 and 2019. These gross monetary losses totaled more than $250
258   million. Median property value in the county dropped by 19%, from $139,400 in 2018 to $112,500 in
259   2019. Almost 60% of residential parcels (n = 4013) lost $10,000 or more in value, while 6% (n = 416) lost
260   half of their 2018 value or more. Just over half of all properties lost between $1 and $30,000 in value
261   (Figure 2A) and two-thirds lost between 0% and 30% of their 2018 value (Figure 2B). The largest absolute
262   monetary loss sustained by a single property was $2.15 million and six properties lost all of their value
263   and more (i.e., by incurring a negative property value in 2019). Only 12% of properties gained value from
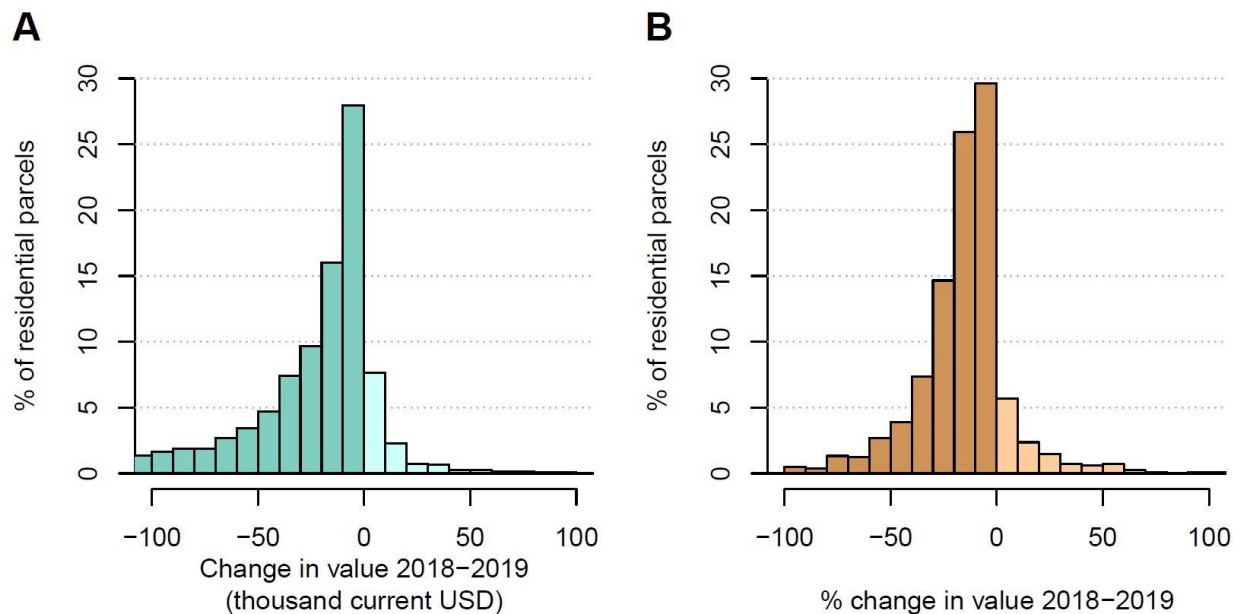264   2018 to 2019, and 3% did not change in value.

265

266   Figure 2. Percent frequency distributions of (A) total and (B) percentage changes in value from 2018-
267   2019 for 6731 Gulf County residential parcels. Darker colour shades indicate parcels with net losses. NB
268   horizontal axes are truncated and actual ranges were $-2.15 million to $0.42 million for (A) and -126% to
269   795% for (B), although only a tiny fraction of parcels had a change in value outside the ranges shown.

270   In terms of housing capabilities lost, our analysis shows that 17% of active residential units (n = 1186)
271   were lost following Hurricane Michael. These losses include 194 active units that became vacant from
272   2018 to 2019, as well as 992 units active in 2018 that disappeared in 2019. Additionally, loss of
273   residential units does not imply a monetary loss in property value from 2018 to 2019 (e.g., if a multi-unit
274   property was converted to a single-unit property with greater value). However, our qualitative

275   assessment suggests the actual losses and damages to housing capabilities are much higher when
276   considering some residential units are still active but in squalid condition due to storm damage.

277   Our analysis of the 5668 residential parcels that suffered monetary loss in value revealed that many
278   properties sustaining very high proportional damages remained active residences (Figure 3A). Of the 413
279   parcels that lost more than half of their value from 2018 to 2019, 84 remained active residential in 2019,
280   including 10 properties that lost more than 75% of their value (Figure 3A), indicating that some residents
281   in Gulf County are living in properties worth only a fraction of their pre-hurricane value. When visiting
282   Gulf County in March 2020, Boda observed the continued widespread use of plastic tarps and other
283   temporary fixes to residential properties in, for example, (North) Port St. Joe and Highland Views. When
284   asked about the severity of impacts on housing quality, the CGCRT director noted that "We don't know
285   how many people are actually homeless now. Some have chosen to just live in nasty conditions, when at
286   least they have a roof over their head." In other locations, such as St. Joe Beach, large portions of the
287   coastal residential areas remain cleared, with only concrete foundations remaining of the properties
288   destroyed in Hurricane Michael. The vast majority (91%) of parcels that lost value and became vacant in
289   2019 sustained losses of more than $10,000 (Figure 3B), yet almost a quarter of vacancies occurred with
290   losses less than 25% of their 2018 value and as little as 0.3% (Figure 3B).
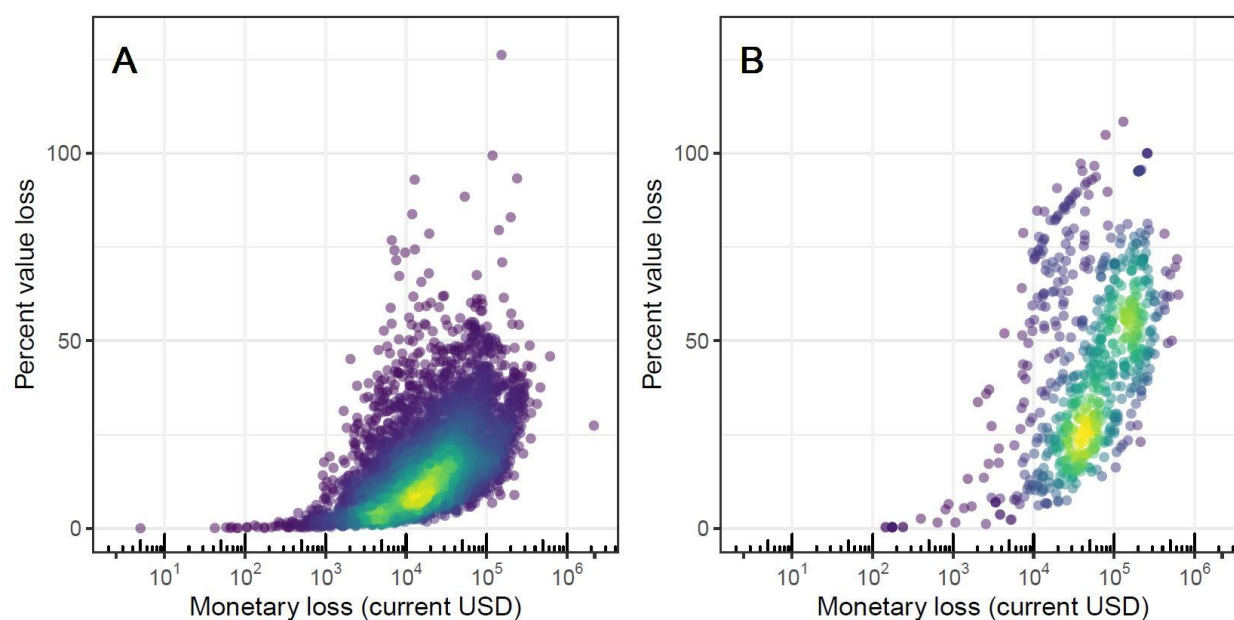

291

292   Figure 3. Absolute monetary losses compared to percentage losses for (A) the 4892 residential parcels in
293   Gulf County that experienced a monetary loss in value but remained active; and (B) the 776 residential
294   parcels that experienced a monetary loss in value and became vacant. Points are coloured by brightness
295   according to increasing density in the plots.

296   **4.2. Census block-level losses and damages**

297   A total of 525 census blocks in Gulf County contained residential properties in 2018, 463 (88%) of which
298   had an average parcel loss (i.e., the average change in value of all parcels within the block was a loss).
299   Average parcel monetary losses were generally higher in blocks along the coast, with less but still

300 significant monetary losses occurring further inland (Figure 4A and B). Some coastal areas show up here
301 as having both high monetary losses and high proportional losses, while other coastal areas with high
302 total losses have retained lower levels of proportional losses. When parcel-level impacts are aggregated
303 to the census block level, our initial analysis did not reveal any strong trends in losses and damages with
304 respect to census block demographics.

305 The distribution of housing unit losses is very uneven (Figure 4C). Some coastal areas again show up as
306 having sustained the greatest amount of housing capability damage, as well as total and proportional
307 property damages. However, other areas which do not show up as having sustained relatively high total
308 or proportional value damages in fact have sustained significant impacts in terms of housing capabilities.
309 Similarly, some census blocks that sustained high total damages do not show up as having sustained
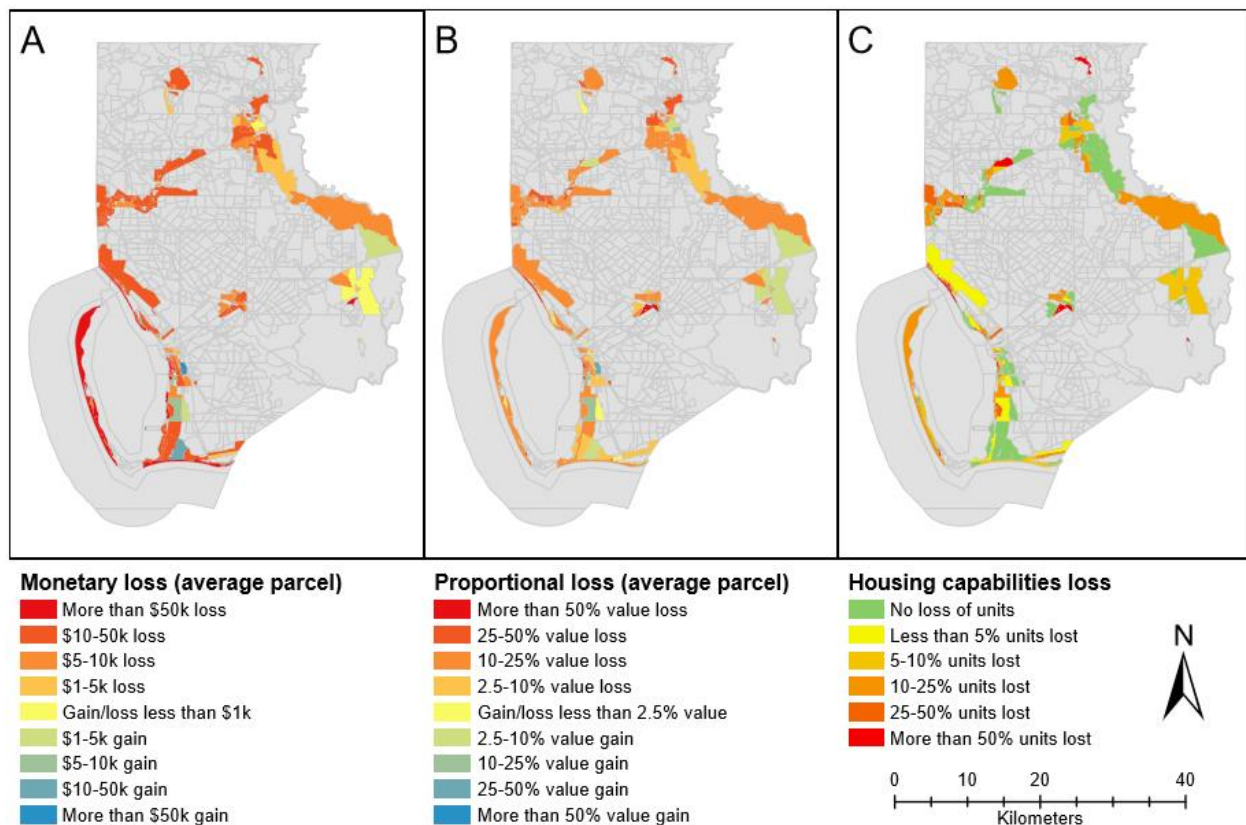310 similarly high levels of housing capability loss.

311

312 Figure 4. Spatial distribution of (A) absolute monetary losses, (B) proportional value losses, and (C)
313 housing capabilities losses at the census block level for Gulf County. Grey blocks are those that did not
314 contain any residential parcels in 2018 (NB agricultural parcels containing farmhouses are not counted as
315 residential parcels).

316 **4.3. Urban cluster-level losses and damages**
317 Urban clusters differed greatly in terms of total value, proportional value and housing capability impacts
318 (Table 2). Net parcel losses across clusters range from $1.2 million (Highland View) to $68 million (Cape
319 San Blas), while proportional losses across clusters ranged from 7% in Highland View to 24% in St. Joe

320 Beach. Average change in parcel value had a wide range from almost $4,677 in North Port St. Joe to
321 almost $75,000 in Cape San Blas. Average proportional change in parcel value ranged between 1% and
322 22%. Residential unit losses ranged from 6% of the housing units in Port St. Joe to 30% in St. Joe Beach.
323 St. Joe Beach and Highland View sustained by far the highest percentage loss of housing units of all
324 clusters.
325
326 Table 2. Parcel losses summarized for the six urban clusters. Clusters are ordered by average parcel value
327 change. All dollar values given in current USD and all percentages given as % of 2018; all losses are
328 indicated by negative sign.

Urban cluster	No. of parcels	Net cluster loss	% net cluster loss	Average parcel value change	Average parcel value change (%)	% residential units lost
Cape San Blas	906	$-67.83 mil.	-18%	$-74,872	-18%	-9%
St. Joe Beach	1266	$-66.27 mil.	-24%	$-52,344	-22%	-30%
PSJ (excl. Nth)	1254	$-35.12 mil.	-18%	$-28,010	-15%	-6%
Wewahitchka	362	$-2.99 mil.	-13%	$-8,264	-15%	-9%
Highland View	205	$-1.20 mil.	-7%	$-5,876	-1%	-23%
North PSJ	598	$-2.80 mil.	-11%	$-4,677	-13%	-10%
All other parcels	2137	$-61.27 mil.	-15%	$-28,670	-10%	-10%

329
330 **4.4. Difference among lenses**

331 Our results show that the three lenses used give very different pictures as to the distribution and
332 magnitude of losses and damages. If the lenses were to give equivalent evaluations of losses and
333 damages, one would expect the rank-order of census blocks to be similar when assessed through each
334 lens, which is not the case in Gulf County (Figure 5). Our results show that large monetary losses do not
335 necessarily imply large losses in housing capabilities (i.e., percent of units lost within a block), and vice
336 versa.

337 The uneven distribution of impacts throughout Gulf County become even clearer when comparatively
338 ranking the six urban clusters along the three lenses used to assess losses and damages (Figure 5). High
339 value properties in Cape San Blas dominate the monetary loss rankings, while less than 10% of housing
340 units were lost in this cluster (Table 2). In contrast, Highland View sustained comparatively low monetary
341 losses per parcel overall, but had massive losses of housing units. North Port St. Joe and Wewahitchka
342 are clustered largely in the upper left corner of Figures 5A and 5C, implying that, while the total
343 monetary damage in these communities was relatively little in comparison to other clusters, e.g. Cape
344 San Blas, they still experienced devastating impacts to property, as reflected in high proportional loss
345 rankings (Figure 5C), as well as in direct housing capabilities, as reflected in high percent unit losses
346 (Figure 5A). Certain urban clusters, such as Port St. Joe and St. Joe Beach, show a distribution indicative
347 of high housing capability losses across parcels that sustained all levels of total or proportional monetary
348 losses (Figure 5A and B). Port St. Joe and St. Joe Beach also show a less skewed relation between total

349   loss rankings and percent loss rankings than lower-income parts of the county; e.g., North Port St. Joe

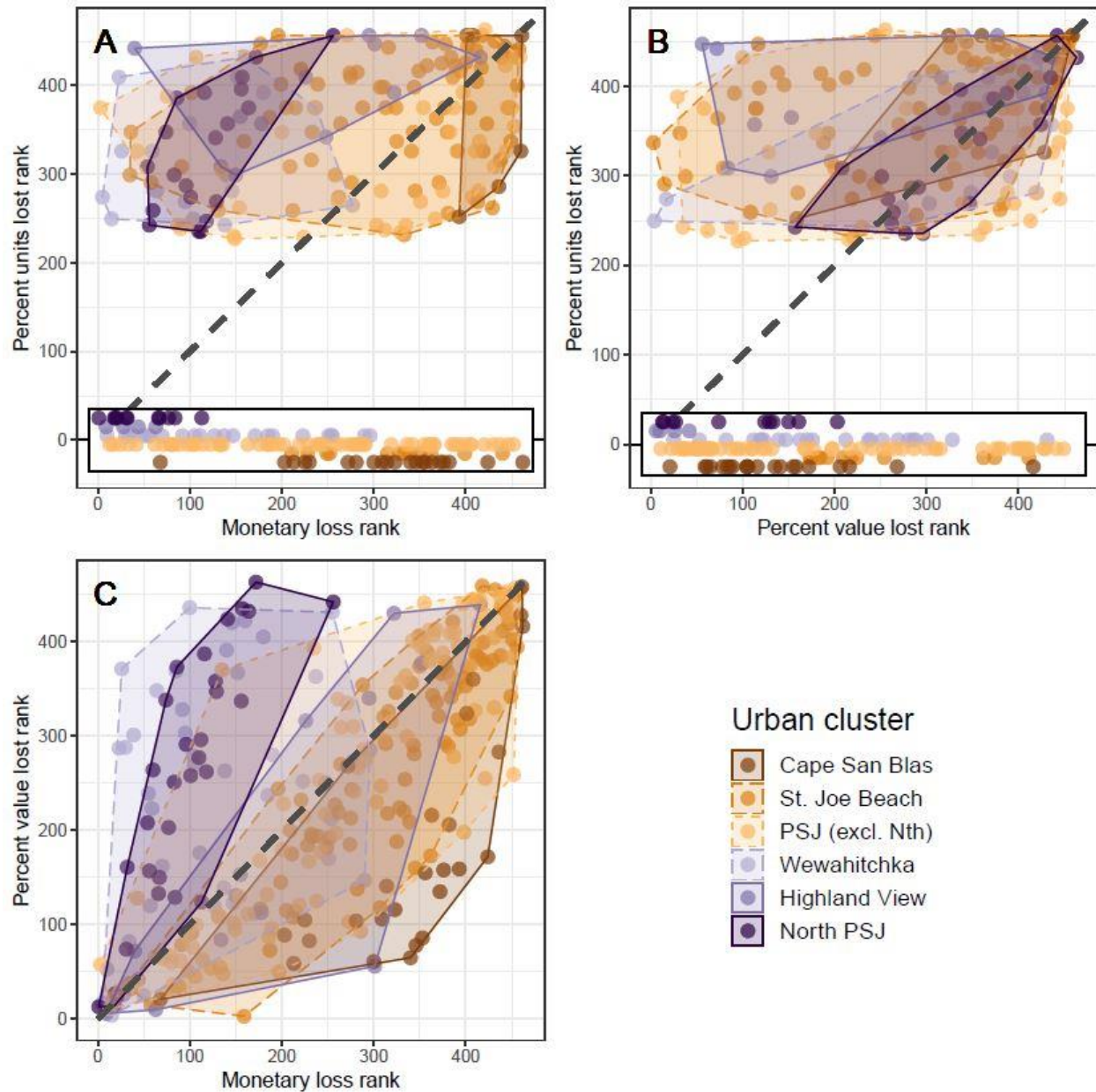350   and Wewahitchka (Figure 5C).

351

352   Figure 5. Comparison of the three lenses used to evaluate losses for the six urban clusters at the census

353   block level. (A) Comparison of rank orders of census blocks by absolute monetary losses (x axis) and

354   housing capabilities losses (y axis). (B) Comparison of rank orders of census blocks by proportional

355   monetary losses (x axis) and housing capabilities losses (y axis). (C) Comparison of rank orders of census

356   blocks by absolute monetary losses (x axis) and proportional monetary losses (y axis). Boxes along zero in

357   panels A and B indicate those census blocks with no housing unit losses. Port St. Joe abbreviated to PSJ in

358   legend. Note: census blocks outside the six urban clusters shown in grey in Figure 1 are excluded here.

359

360 **5. Discussion**

361 **5.1. Interpretation of patterns of disproportionate impacts**

362 The distribution of impacts of Hurricane Michael can largely be explained in terms of exposure, but our
363 results show that the theoretical interpretation of empirical impact patterns leads to quite different
364 appraisals of what constitute high impact areas. A post-hurricane rapid assessment survey by Prevatt and
365 Roueche (2019) found that direct structural storm-surge damages, which were most likely to render
366 properties completely destroyed, were largely confined to Mexico Beach (Bay County), and portions of
367 Port St. Joe (including St. Joe Beach/Beacon Hill and Highland View). Wind-induced damages on the
368 other hand were widespread but not uniform, indicative of the differential exposure and vulnerability of
369 residential properties to different hazards related to the storm. In addition to the differential impacts of
370 storm-surge and wind exposures, our results reveal differential and disproportionate monetary and
371 capability impacts depending upon the theory and evaluation metrics used to approach loss and
372 damage.

373 **5.1.1. Disproportionate impacts from the perspective of Capital theory**

374 From the perspective of capital theory, interpreting housing impacts implies understanding them as loss
375 and damage to housing as a *stock of capital*. In this way, the most relevant information for
376 understanding loss and damage to housing in Gulf County is to focus on the more than $250 million in
377 county-wide aggregate monetary losses. When it comes to the disproportionate distribution of these
378 monetary damages, the focus will be on those areas with the highest monetary losses; in other words,
379 the most impacted areas from the perspective of capital theory are those with the largest quantity of
380 property value lost, which are directly correlated with properties with the highest value.

381 Cape San Blas and St. Joe Beach show up as the most impacted from this perspective, with their
382 collective impacts amounting to just over half (54%) of the total losses across the county. Other areas
383 with lower total monetary losses, even if they have high proportional or capability losses, are ranked
384 comparatively lower in terms of their importance for capital stock restoration. This includes, for
385 example, Wewahitchka, North Port St. Joe and Highland Views, which when combined amount to a total
386 of $7 million in damage, or 3% of countywide damages.

387 With its focus on aggregate monetary damages, other metrics are not relevant to the appraisal of losses
388 and damages to housing from the perspective of capital theory. More precisely, the proportional value
389 losses and the loss of housing unit capabilities are considered to be already sufficiently represented in
390 the aggregate monetary losses.

391 Prevatt and Roueche (2019) also found that homes with certain building characteristics (e.g.,
392 construction year and material types) were correlated with particular degrees and types of damage, with
393 older homes generally fairing worse than newer houses, the latter of which may be more likely to adopt
394 code-plus construction standards (i.e., applying best practices rather than simply meeting minimum
395 requirements). This suggests disproportionate impacts at the parcel level likely depend on housing
396 quality and age, which have important implications for individuals living in these houses regardless of the
397 total value of the property being impacted. Here, capital theory offers little insight.

398 **5.1.2. Disproportionate impacts from the perspective of the capabilities approach**

399 From the perspective of the capabilities approach, interpreting housing impacts implies understanding
400 them as loss and damage to housing that leads to the *deprivation of individual capabilities.* The most
401 relevant information, then, is not the aggregate monetary losses as in capital theory, but the
402 disaggregated impacts on households and their individual capacity to continue to lead quality lives,
403 including being adequately housed. When it comes to the disproportionate distribution of impacts, the
404 capabilities approach aims to focus on those residents who are the least well off, recognizing that there
405 are qualitatively different kinds of capability deprivation connected to pre-existing inequalities in
406 capability sets and functioning achievements, including for example differences in housing quality.

407 The difference between proportional and total losses that we have shown is instructive. Our results
408 reveal that impacts viewed through the lens of proportional monetary losses (an indication of the
409 *severity* of impact to a property) highlight different highly-impacted areas than those under capital
410 theory. North Port St. Joe, for example, sustained very high levels of proportional property value loss,
411 even though it ranks relatively low in terms of total damage levels. This is, first, an indication that many
412 houses in North Port St. Joe were severely damaged in the storm (even if they did not become vacant)
413 and, second, that the high proportional losses potentially represent a major hit to intergenerational
414 wealth in an already low-income community. The importance of recognizing the qualitative difference
415 between total and proportional damages, and their implications for low-income households, has been
416 noted by other loss and damage researchers as well (van der Geest, 2018).

417 Comparing high value losses and high housing capability losses brings out further important differences.
418 Many places with lower levels of monetary damage (i.e., low property values to begin with) experienced
419 very high levels of housing unit loss, for example Wewahitchka and Highland View, implying a significant
420 loss in the ability to house residents. Some of the urban clusters with high unit losses are also the
421 poorest parts of the county, which suggests their residents are also the most vulnerable to housing
422 insecurity. From this capabilities perspective, areas with high proportional losses *and* high vacancy rates,
423 as seen for example in certain blocks of Port St. Joe, North Port St. Joe, Highland View and Wewahitchka,
424 could be considered potential depravation hotspots.

425 **5.2. Policy implications**

426 Our results show that the theoretical interpretation of impact data has big implications for what gets
427 considered a "highly-impacted" area. For example, capital theory would focus on the areas experiencing
428 the highest monetary losses and damages, which draws attention to Cape San Blas and St. Joe Beach as
429 hotspots for capital loss and thus foci for capital compensation and restoration. On the other hand, the
430 capabilities approach would focus on the losses and damages occurring in those places with high
431 proportional and capability losses, which draws attention to North Port St. Joe and Wewahitchka as
432 hotspots of housing capability deprivation. Another important difference is that capital theory aims to
433 aggregate losses and damages at the societal (e.g. county-wide) level, while the capabilities approach
434 emphasizes the disaggregation of impacts in order to locate more precisely the households which are
435 suffering from housing capability deprivation.

436 Our findings have important implications for policy response. In the wake of Hurricane Michael, and after
437 extreme events more generally, response came in three different forms – government recovery
438 assistance, private insurance, and volunteer organizations. In Gulf County this included federal and state
439 agencies, including the U.S. Federal Emergency Management Agency (FEMA) and Emergency
440 Management personnel, as well as private insurance firms. Civil society NGOs, including regional
441 branches of international organizations such as the Red Cross, Salvation Army, United Way, Samaritan's
442 Purse, among others, were also active, including numerous regional Florida NGOs such as Doorways of
443 Northwest Florida. As we have seen, the interpretation of losses and damages through either capital
444 theory or the capabilities approach determines which areas are considered most impacted; likewise, the
445 theory of loss and damage has important implications regarding what recovery organizations and the
446 policies that guide them should prioritize.

447 **5.2.1. Loss and damage policy response under capital theory**

448 From the perspective of capital theory, addressing losses and damages implies compensating the value
449 of capital investments to return them to previous (or, preferably, higher) levels. The restoration of
450 capital stock is the priority, especially for high value properties. In the United States, some of this lost
451 capital is recovered through government recovery programs, such as FEMA post-disaster grants
452 (McCarthy, 2010). However, studies have shown that, in the United States, the federal government's
453 roles in post-disaster capital restoration is relatively minor, with FEMA often covering only small
454 percentages of the total damages that occur in an extreme event (Kousky, 2013).

455 Private insurance typically covers much more of the damages than state disaster assistance, though still
456 generally not entirely. Private insurance is often touted as a possible mechanism for managing the risks
457 of loss and damage from climate change (Broberg, 2019; Lashley & Warner, 2015; Nordlander et al.,
458 2019), and this is largely the default in the United States—i.e., market-based recovery policy. According
459 to the Florida Office of Insurance Regulation, in Gulf County total insurance pay out for all residential
460 claims, as of the last data call on October 26, 2019, was over $283.8 million. These claims are divided
461 among different residential categories, with homeowners receiving $183,766,000, dwellings
462 $76,838,000, mobile homeowners $10,435,000 and commercial residential $12,788,006. Since in this
463 study we are interested in physical impacts to housing specifically (which are captured in the just value
464 assessment provided by the Florida Tax Authority), the most relevant category is "dwelling", which
465 suggests that 30% of the county-wide housing impacts have been covered by private insurance.

466 Volunteer organizations, such as the Red Cross, make a smaller but still significant contribution to the
467 resources available to communities to restore lost capital. The Red Cross, for example, made over $12.4
468 million in direct cash payments to over 8,400 households across the Florida counties impacted by
469 Hurricane Michael to assist in fixing homes and replacing damaged appliances (Red Cross, n.d.).

470 **5.2.2. Loss and damage policy response under the capabilities approach**

471 Longitudinal surveys (Peacock et al., 2014; Zhang & Peacock, 2009) of long-term housing recovery have
472 shown major problems with the standard market-driven approach to housing recovery after storms in
473 Florida and elsewhere in the United States, with affected neighborhoods facing housing market volatility,
474 high rates of property abandonment, and uneven resources for and rates of housing recovery. Other

475 longitudinal studies of post-disaster recovery have shown that the United States' strategy of focusing on
476 restoration of capital in post-disaster recovery can actually work to deepen pre-existing wealth
477 inequalities (Howell & Elliott, 2019).

478 A capabilities approach would directly and intentionally focus on restoration of basic needs and
479 functioning ability, starting with the least well-off first. This would include for example fixing damaged
480 houses, or securing adequate temporary/replacement housing for those most in need. This is because
481 housing is viewed as a basic precondition to make sure people can continue to access income generating
482 employment, and health/educational facilities for vulnerable groups (elderly, children, sick). When asked
483 what are the major challenges the long-term recovery group was facing after Hurricane Michael, the
484 CGCRT Director responded "First, Housing. Second, Housing. Third, labor force for building houses, which
485 itself requires housing!"

486 The capabilities perspective would take notice, for example, that many of the residential buildings in
487 Cape San Blas and St. Joe Beach are vacation rentals, as indicated by the zoning of these areas as "mixed
488 residential commercial". Following this, even if sections of Gulf County have the highest total monetary
489 losses, it might not be pertinent to rebuild a wealthy person's second vacation house, for example,
490 before lower income residents have secured a single quality home for themselves. This is recognized in
491 the mission of the CGCRT: as the Director expressed it, "Our mission is to work with individuals and
492 families who have no other means to recover. They are SOL, no money for repairs, no or limited FEMA
493 money, no or limited insurance money."

494 The role of government in disaster response is also relatively minor, and sometimes conflicting, in terms
495 of capabilities restoration. In Gulf County, the CGCRT acknowledged FEMA had been helpful, but that
496 recovery groups are not provided with enough resource to help on the scale needed. Some critics even
497 argue that federal disaster relief programs provide perverse incentives for residents to forgo investing in
498 private insurance (Kousky et al., 2018), or even to build in risky locations (Kousky & Shabman, 2012).

499 Private insurance can be of immense help in restoring housing capabilities, if residents have it.
500 Importantly, even for many households that do have it, private insurance does not cover all damage
501 problems. A sample of 185 Gulf County households analyzed by World Renew Disaster Response
502 Services, in service of the CGCRT, showed that these households alone required over $6.7 million in
503 reconstruction costs, while only $1.7 million of this was insured. Accounting for damage to the contents
504 of these households would add another $620,000 to these uninsured costs. Given that large portions of
505 these households were elderly (45%) or disabled (25%), the ability of these households to afford
506 adequate insurance coverage is questionable, and this would not address their current situation anyway.

507 Other organizations, such as Red Cross and faith-based volunteers, significantly fill the gap left beyond
508 state aid and private insurance in terms of restoring housing capabilities. Such organizations help in a
509 variety of ways, including financial compensation, but also organizational advice, information processing,
510 and legal advice. However, no-one is responsible for coordinating these NGO activities, which is why the
511 CGCRT was formed in the first place following Hurricane Michael.

512 Addressing the housing capability needs of the least well off following a disaster requires identifying and
513 contacting needy citizens, but this is not so easy. In the case of Hurricane Michael, the CGCRT does not

514 know exactly who was impacted, how much, and where. In the absence of official help, many citizens
515 simply adjust to lower quality conditions—as noted by the CGCRT director when she said "We don't
516 know how many people are actually homeless now. Some have chosen to just live in nasty conditions,
517 when at least they have a roof over their head." Adopting a capabilities approach to evaluating highly
518 impacted areas, as opposed to a capital theory approach, would help to identify such hotspots of
519 housing capability losses.

520 **5.3. Attribution and future risk of loss and damage from climate change**

521 A global inventory for the impacts of anthropogenic climate change does not yet exist, in part because
522 no agreement has been reached regarding how impacts from climate-related hazards (i.e., loss and
523 damage) should be conceptualized or measured, nor what would constitute high quality evidence (Otto
524 et al., 2020). In this article, we are not claiming to have directly attributed the housing impacts we
525 measure to some degree of anthropogenic influence on Hurricane Michael. To the best of our
526 knowledge, no event attribution study has been conducted on this particular storm. However, we argue
527 that it is reasonable and fruitful to view the housing impacts in Gulf County *as if* they were loss and
528 damage from climate change. We find this reasonable because, as (Patricola & Wehner, 2018) have
529 shown, even though there is not yet a clear signal of anthropogenic influences on current tropical
530 cyclone activity emerging from the available literature, the process theory relating anthropogenic
531 warming to increased tropical cyclone intensity is well established, and a variety of models consistently
532 show significant increases in tropical cyclone intensity over the next century under different warming
533 scenarios. This suggests that limit-breaching storms like Hurricane Michael will likely be more common in
534 the future. Furthermore, given the rapid advancements in the area of event attribution science (Otto,
535 2017; Otto et al., 2018; van Oldenborgh et al., 2020), we might soon be able to more definitively show
536 anthropogenic influence on current tropical cyclone behavior; e.g., by more effectively disentangling the
537 regional-climate-variability sea surface temperature anomalies from over-all warming trends. Since we
538 can predict with some confidence that tropical cyclone intensity will increase as the globe warms, a
539 better understanding of what kinds of impacts occur from limit-breaching tropical cyclones and how to
540 best interpret these impacts is urgently needed. Such insight can help provide policy makers and citizens
541 with an opportunity to better prepare for, respond to, and potentially *prevent* (as opposed to minimize
542 or address) loss and damage resulting from climate change-enhanced tropical cyclones.

543 In addition to improving attribution, and given the evidence that class, race, gender and age
544 discrimination have been common characteristics of, even exacerbated by, the status quo disaster
545 recovery process in the United States (Howell & Elliott, 2018, 2019), more longitudinal monitoring and
546 research (both quantitative and qualitative) into inequalities in loss and damage recovery processes is
547 needed. Such research and monitoring can help to better understand how different forms of
548 discrimination come about, and thus to attempt to better predict who is most at risk of discrimination,
549 where and why. This may better allow for the formulation of policy that minimizes the potential for
550 discrimination when addressing loss and damage impacts from climate change across vulnerable and
551 exposed sectors and places.

552 **6. Conclusions**

553 In this article, we have provided empirical measurements of loss and damage-like impacts to residential
554 properties in Gulf County occurring from Hurricane Michael. We reported widespread and devastating
555 impacts, with nearly 90% of county-wide residential properties sustaining losses, and 18% of total
556 residential units being lost between 2018-2019. Our interpretation of these impacts through different
557 theories of loss and damage and their implications suggests that the capital theory and capabilities
558 approaches lead to different appraisals of where is considered "most impacted", as well as implying
559 quite divergent policy priorities. We conclude from our analysis and interpretation that the capabilities
560 approach is promising as a more comprehensive and human-centered approach to loss and damage
561 when compared to capital theory.

562 **Acknowledgements**

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