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Equity Weighting in Flood Risk Assessment in Data Scarce Environments

Accra Ghana Case Study

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Summary

Expected Annual Damage (EAD) is widely used in flood risk assessment because it provides a compact measure of average annual monetary damage and supports comparison across places and interventions. Its limitation is distributive. Standard EAD shows how much damage is expected, but not who bears that damage. Equal monetary losses therefore carry equal weight regardless of the welfare conditions of the affected population.

This note examines whether equity-weighted EAD can serve as a companion metric to standard EAD in Accra, Ghana. The method leaves the underlying hazard, exposure, and vulnerability modeling unchanged. It instead modifies the aggregation of modeled damages by assigning greater relative weight to damages borne in lower-welfare districts. The aim is not to replace conventional EAD, but to test whether a distribution-sensitive metric can be implemented with obtainable proxy data and whether it changes interpretation in a meaningful way.

The results show a clear but bounded effect. At citywide scale, equity weighting increases total EAD only modestly. Under the baseline specification, citywide amplification remains close to unity. Under the sensitivity specification, amplification is somewhat larger. The main effect is therefore not a substantial increase in total damage, but a change in the relative contribution of districts to the weighted total.

At district scale, equity weighting changes magnitudes more than rankings. Under the baseline specification, most districts remain close to the unweighted case and rank changes are limited. Under the sensitivity specification, amplification becomes more differentiated and selected mid-ranked districts, especially La-Nkwantanang-Madina, become more prominent. The highest-damage districts nevertheless remain the principal priorities in all specifications. The broad metropolitan geography of damage is therefore stable, while the ordering within the middle tier becomes more sensitive to welfare conditions.

This matters most where resources are limited. If intervention is directed only to the first seven districts, the sensitivity-weighted ranking shifts attention toward a district containing a substantially larger population than under the unweighted ordering. Once the portfolio expands, however, the same districts largely remain in scope and cumulative population coverage becomes more similar. The value of equity weighting therefore lies not in redefining the whole damage landscape, but in refining prioritization at the margin.

The Accra case also shows that district-level welfare proxy data are sufficient to produce a usable weighting signal in a data-constrained setting. At the same time, the results remain sensitive to how the welfare proxy is constructed and scaled. Sensitivity analysis should therefore be treated as part of the core result. Equity-weighted EAD is best understood as a companion metric to conventional EAD: feasible to implement, useful for screening and prioritization, and explicit about the distributional implications of aggregation.

Contents

1 Purpose and scope

1.1 Purpose

The purpose of this workflow is to supplement standard monetary EAD with an equity-weighted EAD that is more sensitive to losses borne by lower welfare populations. The aim is to assess whether equity-weighted EAD can serve as a standard companion metric to unweighted EAD for hotspot screening, intervention prioritization, and communication of flood impacts in socially heterogeneous urban settings.

1.2 Scope

The scope of this note is deliberately narrow, the focus is specifically on Accra and we report the results at a district level, with subbasin implications used for interpretation. The main outputs are unweighted EAD and equity-weighted EAD, together with district amplification factors, district ranking comparisons, and sensitivity bands.

The analysis is based on a baseline weighting specification and an alternative sensitivity weighting specification. The purpose of this comparison is not to establish a single definitive weighting scheme, but to test how strongly the results depend on the construction and scaling of the welfare proxy. This keeps the method operational in a data-constrained context while making the role of normative and technical choices explicit.

2 Conceptual approach

2.1 From asset damages to distribution-sensitive aggregation

In a standard flood risk workflow, expected annual damage is obtained by aggregating monetary damages across exposed assets and across a range of flood return periods. This produces a useful measure of economic loss, but it treats one unit of damage as equivalent regardless of the welfare level of the affected population. Yet, from a distributional perspective, the same monetary loss may have different social significance depending on who experiences it. This is the starting point of equity weighting. Equity-weighted EAD modifies only the aggregation step. What explicitly changes is the social valuation of marginal losses across the welfare distribution (Atkinson, 1970; Fleurbaey and Martinet, 2014).

2.2 Normative parameterization

As with any distribution-sensitive metric, the method involves normative choices. The method includes a curvature parameter, η, that governs the degree of priority assigned to lower welfare groups. A higher curvature implies greater relative weight on losses borne by lower welfare populations. Because there is no single universally accepted value, two values are reported as a sensitivity band.

The weighting results also depend on how welfare conditions are represented. For that reason, the analysis compares a baseline weighting specification with an alternative sensitivity weighting specification. The purpose is not to eliminate normative choices, but to make them explicit and to show how strongly the findings depend on them. In practical terms, this allows the weighted outputs to be interpreted as a structured sensitivity around the unweighted baseline rather than as a single fixed social valuation.

2.3 Exposure and damage results

The workflow assumes that flood impact results are available by event and spatial unit from the underlying model chain. In the Accra case, damages are summarized to district level and linked to subbasins for interpretation.

2.4 Welfare and poverty proxy inputs

A practical challenge in applying equity weighting is that household welfare data are often incomplete, unavailable, or inconsistent with the spatial resolution of flood damage outputs. In such cases, proxy approaches are needed. The key requirement is a welfare-related indicator that varies monotonically across districts and can be normalized for weighting. Field observations also illustrate the built conditions that sit behind the proxy-based weighting logic, including visible flood damage to residential structures and local adaptation through elevated housing in flood-prone areas of Accra (Figure 1).

Figure 1. Illustrative housing conditions in flood-prone areas of Accra. Left: residential flood impact, with the reported flood level indicated on the wall. Right: elevated housing as a local adaptation to recurrent flood exposure. The images provide contextual grounding for the proxy-based, distribution-sensitive interpretation of district-level damages.

In Ghanaian and similar settings, several nationally grounded sources may be suitable for this purpose. These include census-derived socioeconomic indicators such as housing quality, access to services, and education proxies, gridded poverty or wealth surfaces calibrated to national surveys, and administrative poverty registries or targeting datasets where available (World Bank, 2021).

The baseline approach adopted here is explicitly national in orientation. International poverty line variants can be constructed in parallel to test the sensitivity of results to alternative threshold definitions and scaling assumptions.

3 Methods

3.1 Computing EAD

For each district d, expected annual damage is obtained from object-based damage estimates for each return period and integration across all return periods. This provides the standard unweighted EAD, while the Equity-weighted EAD is then defined as:

$$\mathrm{EADdEW} = \mathrm{wd}(\eta)\mathrm{EADd}$$

where wd (η) is the district-specific weight derived from the welfare proxy and the curvature parameter η.

City-wide values are computed as sums across districts. Subbasin implications are obtained by linking districts to subbasins and aggregating accordingly. Since the boundaries of administrative districts and hydrologic units do not align perfectly, subbasin interpretation should be understood as indicative rather than exact.

3.2 Diagnostics for interpretation

For the Accra case, the welfare input for the equity analysis was represented through a district-level proxy linked to the residential EAD results. This proxy was assembled from multiple obtainable sources rather than taken from a single ready-made dataset. The main poverty incidence input was drawn from the *Ghana Poverty Mapping Brief*, based on GLSS7 and the 2010 Population and Housing Census for 2016/17. Additional poverty distribution parameters were taken from the *Poverty Profile in Ghana (2005–2017)*, while a Greater Accra regional Gini value was used to support the construction of the sensitivity weighting specification. The Greater Accra regional Gini value was used not as a district-level welfare measure in itself, but as a contextual parameter to inform the sensitivity of the weighting specification to underlying regional inequality. Population totals used for interpretation were taken from the Deltares 2024 Accra flood risk assessment database. Because some poverty estimates were reported for an earlier district structure, they were translated to the current Metropolitan, Municipal and District Assemblies (MMDA) boundaries through a district crosswalk.

The analysis then applies a baseline weighting specification together with a sensitivity weighting specification to test how strongly the results depend on the construction and scaling of the welfare proxy. This is important because the weighting signal is shaped not only by the spatial distribution of monetary damages, but also by how welfare conditions are represented in the proxy data. In that sense, the sensitivity analysis is not separate from the interpretation of the results. It is part of showing how robust the distributional signal remains under plausible alternative representations of deprivation.

3.3 Sensitivity analysis

Sensitivity is examined along two dimensions. The first is the curvature parameter, with $\boldsymbol{\eta} \in \{\boldsymbol{\eta_1}, \boldsymbol{\eta_2}\}$ reported as a band. The second is the weighting specification, with a baseline proxy-based weighting used as the main case and an alternative sensitivity weighting used to test robustness.

The resulting variation is best communicated through amplification bands and ranking stability measures, for example overlap in the top-ranked districts across specifications, rank correlation statistics, and maximum rank displacement. In this way the sensitivity analysis supports interpretation rather than sitting outside it. This is especially important in cases such as Accra, where amplification patterns carry more information than rank reversals alone.

4 Results

4.1 Citywide comparison

Citywide results (Table 1) show that equity weighting increases total EAD only modestly, with larger effects under the sensitivity weighting specification than under the baseline specification.

Table 1. Citywide EAD summary, comparing unweighted and equity-weighted values under the baseline and sensitivity weighting specifications.

Metric	η = 1.2	η = 1.5
Unweighted citywide EAD (USD)	$ 196,087,886	$ 196,087,886
Equity-weighted citywide EAD, baseline specification (USD)	$ 198,010,840	$ 198,517,944
Equity-weighted citywide EAD, sensitivity specification (USD)	$ 202,241,179	$ 203,984,303
Amplification factor, baseline specification	1.0098	1.0124
Amplification factor, sensitivity specification	1.0314	1.0403

At the citywide level, the main signal is not a substantial reshaping of total damages, but a redistribution in the relative contribution of districts to the weighted total. Table 1 shows that amplification remains modest under all specifications, but is consistently higher under the sensitivity specification than under the baseline specification. It also increases slightly as η rises from 1.2 to 1.5. In absolute terms, this means citywide EAD increases from USD 196.1 million unweighted to USD 198.0-198.5 million under the baseline specification and USD 202.2-204.0 million under the sensitivity specification. This corresponds to an increase of about 1.0-1.2 percent under the baseline specification and 3.1-4.0 percent under the sensitivity specification**.** This indicates that the citywide result is sensitive both to the curvature of the weighting function and to how the welfare proxy is constructed, while remaining limited in magnitude. Because some districts are upweighted and others are down weighted, part of the effect offsets at metropolitan scale, and the highest-damage districts remain dominant across specifications. The value of the method therefore lies less in changing aggregate citywide damage than in showing where socially weighted damages become more prominent relative to standard monetary damages.

4.2 District amplification and ranking

The district results show that equity weighting affects magnitudes more strongly than rankings. Under the baseline weighting specification, most districts remain close to the unweighted baseline. Amplification factors range from about 0.97 to 1.05 for $\eta = 1.2$ and from about 0.96 to 1.07 for $\eta = 1.5$. This indicates relatively modest departures from the unweighted case. The largest upward adjustment under the baseline weighting occurs in La Dade-Kotopon, while Tema West, Tema Metropolitan, and the Ablekuma municipalities are modestly downweighted. Adenta remains the highest-damage district in every specification and is slightly amplified under the baseline weighting specification.

The sensitivity weighting specification produces a more differentiated pattern. Here the amplification range widens to roughly 0.96 to 1.19 for $\eta = 1.2$ and to roughly 0.96 to 1.24 for $\eta = 1.5$. The clearest upward shifts occur in Adenta and La-Nkwantanang-Madina. Under this specification, Adenta increases by nearly 19 percent at $\eta = 1.2$ and by about 24 percent at $\eta = 1.5$, while La-Nkwantanang-Madina increases by roughly 8 to 10 percent. By contrast, Kpone Katamanso, Krowor, La Dade-Kotopon, and Ledzokuku are downweighted under the sensitivity weighting specification.

Table 2. *District comparison of unweighted EAD, amplification factors, and largest rank change relative to the unweighted ordering under the baseline and sensitivity weighting specifications*

District	Unweighted EAD (USD million)	Baseline amplification (η = 1.2–1.5)	Sensitivity amplification (η = 1.2–1.5)	Unweighted rank	Largest rank change vs. unweighted
Adenta Municipal	50.42	1.033–1.041	1.188–1.241	1	0
Kpone Katamanso	38.56	1.017–1.022	0.965–0.957	2	0
Ledzokuku Municipal	20.01	0.985–0.981	0.965–0.957	3	0
Tema West Municipal	17.39	0.967–0.959	0.969–0.961	4	0
Ashaiman Municipal	13.74	1.006–1.008	1.011–1.014	5	0
Krowor Municipal	13.48	1.017–1.022	0.965–0.957	6	0
Ayawaso West	11.61	0.977–0.972	0.976–0.970	7	-1
La Dade-Kotopon	11.60	1.054–1.068	0.965–0.957	8	+1
La-Nkwantanang-Madina	10.51	1.001–1.001	1.078–1.099	9	+2
Tema Metropolitan	9.08	0.976–0.970	0.969–0.961	10	0
Ablekuma West Municipal	5.62	0.977–0.972	0.976–0.970	11	0
Ablekuma Central Municipal	3.99	0.985–0.981	0.976–0.970	12	0
Ablekuma North Municipal	0.37	0.977–0.972	0.976–0.970	13	0

In ranking terms, the district pattern is fairly stable. Most districts do not move at all. Under the baseline weighting specification, only two changes occur: La Dade-Kotopon rises from 8th to 7th, while Ayawaso West drops from 7th to 8th. Under the sensitivity weighting specification, the most notable shift is La-Nkwantanang-Madina, which rises from 9th to 7th, while Ayawaso West falls from 7th to 8th and La Dade-Kotopon falls from 8th to 9th. Thus, equity weighting does not overturn the overall geography of damage in Accra, but it does alter the relative priority of a small set of mid-ranked districts.

4.3 Population implications under limited prioritization

The population comparison makes the limited-prioritization effect more concrete. Under the unweighted ranking, the top seven districts are Adenta, Kpone Katamanso, Ledzokuku, Tema West, Ashaiman, Krowor, and Ayawaso West, together containing about 1.49 million residents. Under the baseline weighting specification, the only change is that La Dade-Kotopon replaces Ayawaso West, increasing the covered population to about 1.56 million. Under the sensitivity weighting specification, La-Nkwantanang-Madina rises into the top seven instead, increasing the covered population further to about 1.66 million. Thus, if preventive resources were allocated only to the first seven districts, the sensitivity-based ranking would direct attention toward an area containing roughly 170,000 more residents than the unweighted ranking, and about 105,000 more than the baseline weighted ranking. Once the top eight or top nine districts are included, however, the cumulative population covered becomes much more similar because the same districts remain in the portfolio, only in a different order.

District by district, this effect is concentrated in the middle of the ranking. The first five priorities remain unchanged under every specification: Adenta, Kpone Katamanso, Ledzokuku, Tema West, and Ashaiman. This means that the broad strategic picture does not shift. The districts with the largest baseline damage burdens continue to dominate prioritization. What changes is the order among the middle tier. Under the sensitivity weighting specification, La-Nkwantanang-Madina rises from ninth to seventh, overtaking both Ayawaso West and La Dade-Kotopon. Because La-Nkwantanang-Madina has a population of about 244,676, compared with about 75,303 in Ayawaso West and 140,264 in La Dade-Kotopon, this shift would likely direct preventive investment toward a district where both more people are present and the welfare weighting indicates stronger distributive concern.

4.4 Sensitivity to weighting specification

The comparison between weighting specifications shows that the results are sensitive to how the welfare proxy is constructed and scaled. The baseline specification remains close to the unweighted case, while the sensitivity specification produces a wider spread of amplification factors and stronger upward adjustment in selected districts, especially Adenta and La-Nkwantanang-Madina. Even so, the overall priority structure remains stable, with the main effect concentrated in the middle of the ranking..

5 Discussion

The Accra case helps clarify what equity weighting is doing in practice. It does not change the hydrodynamic behaviour of the system, the exposure data, or the vulnerability assumptions used in the underlying flood impact model. Nor, in this case, does it fundamentally reorder the metropolitan pattern of damage across the city. What it changes is the relative magnitude attached to losses in different districts once those losses are interpreted through a welfare-sensitive lens.

In many applications, the expectation may be that equity weighting should produce substantial rank reversals. The results of this assessment suggest a more measured interpretation. Where the underlying damage geography is already pronounced, equity weighting may leave the broad ordering intact while still shifting the relative emphasis placed on particular districts. In that sense, the method does not replace the existing priority structure. Rather, it sharpens it by distinguishing between districts with similar damage totals but different welfare conditions.

This also helps explain why rank changes are limited. The unweighted EAD results are already concentrated in several populous and socially vulnerable districts, especially Adenta and Ashaiman. In part, this reflects the spatial structure of vulnerability in Accra itself, where many lower welfare households are concentrated at relatively high densities in marginal land that is already known to be flood prone, including low-lying and poorly drained areas where exposure and vulnerability compound one another. As a result, the baseline damage pattern already captures part of the broader social vulnerability signal. The weighted results therefore do not overturn the main priority structure. Instead, they refine it.

5.1 Operational feasibility, proxy adequacy, and reproducibility

The Accra case suggests that equity weighting can be applied consistently in routine practice. The required inputs were not available as a single ready-made dataset and had to be assembled from multiple sources, but they were still obtainable in a relatively data-constrained setting. Because the method is applied as a post-estimation valuation layer rather than through a new hazard or damage model, it is comparatively simple to integrate into existing impact assessment workflows.

The case also suggests that proxy-based welfare weighting is sufficient for routine screening, especially when the main objective is to identify where weighted damages diverge from standard damages rather than to estimate household welfare precisely. The credibility of the method depends less on mathematical sophistication than on clearly documenting how the welfare proxy was sourced, oriented, normalized, and translated into weights. For operational use, this means reproducibility should be treated as part of the reporting standard. The proxy inputs, transformation steps, parameter values, and sensitivity cases should all be described clearly enough that the workflow can be repeated in another city or by another analyst.

5.2 Implications for standard practice

For application, the Accra case suggests that equity-weighted outputs should be treated as a complement to, not a replacement for, conventional EAD. A minimum reporting standard should therefore include unweighted EAD and equity-weighted EAD side by side, together with district amplification factors, district rank comparisons, rank-shift diagnostics, a curvature sensitivity band, and a concise description of the welfare proxy and any transformations applied.

In this case, amplification patterns and threshold-based prioritization effects are more informative than rank changes alone, because they show where the weighting signal is substantive even when the overall ordering remains largely stable. Districts that remain highly ranked under both unweighted and weighted metrics can be treated as robust priorities, while districts that rise only under weighted specifications indicate where losses carry greater relative importance under the welfare-sensitive valuation. The main value of equity weighting therefore lies in improving the ordering of districts when choices are tight, especially where budgets are fixed, interventions must be phased, or only a subset of districts can be targeted in the near term.

More broadly, the case indicates that equity weighting is sufficiently feasible, reproducible, and operationally light to be treated as a standard companion output in future flood impact assessments.

5.3 Limitations

Several limitations should be noted. First, equity-weighted metrics necessarily involve normative choices. The curvature parameter and the construction of the welfare proxy both influence the results, and should therefore be documented clearly and tested through sensitivity analysis. In this sense, transparency is part of the method itself.

Second, the present workflow is best suited to comparative screening and prioritization rather than fine-grained distributional diagnosis. It identifies where socially weighted damages diverge from standard monetary damages, but it does not by itself explain the causal pathways behind those differences or identify specific households at risk.

Finally, the Accra case should be interpreted as case-specific evidence. The relatively small rank shifts observed here partly reflect the fact that the unweighted damage pattern already overlaps to an important extent with the spatial distribution of lower-welfare districts captured by the proxy. In another city, or under a different exposure pattern, the same workflow could produce stronger re-ranking.

6 Conclusions

Equity-weighted expected annual damage offers a practical way to complement conventional flood damage metrics with a distribution-sensitive perspective. The Accra 2024 case study shows that, when welfare-sensitive weights are introduced into the aggregation of damages, the resulting effect is stronger in magnitude than in rank order. The broad geography of damage remains stable, but the relative prominence of selected districts changes.

An equally important finding concerns the practical viability of the method. The workflow is obtainable and reproducible. The required data were not trivial to assemble and had to be sourced from a variety of places, but they were still obtainable in a context that would reasonably be described as data-scarce. Because it operates as a post-estimation valuation step on standard damage outputs, it can be incorporated into existing impact assessment workflows without requiring major changes to the underlying modelling chain.

For practice, equity weighting should be treated as a standard companion metric to conventional EAD rather than as a one-off analytical extension. Its value lies in showing where socially weighted damages diverge from standard monetary damages and in improving prioritization where prevention resources are limited. More broadly, the Accra case shows that distribution-sensitive metrics can be integrated into routine flood risk practice through a method that is transparent, reproducible, and feasible in data-constrained settings.

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