

# Supplementary Information (SI)

## Incomplete recoveries may have aggravated the poverty effects of recurrent floods in the Philippines

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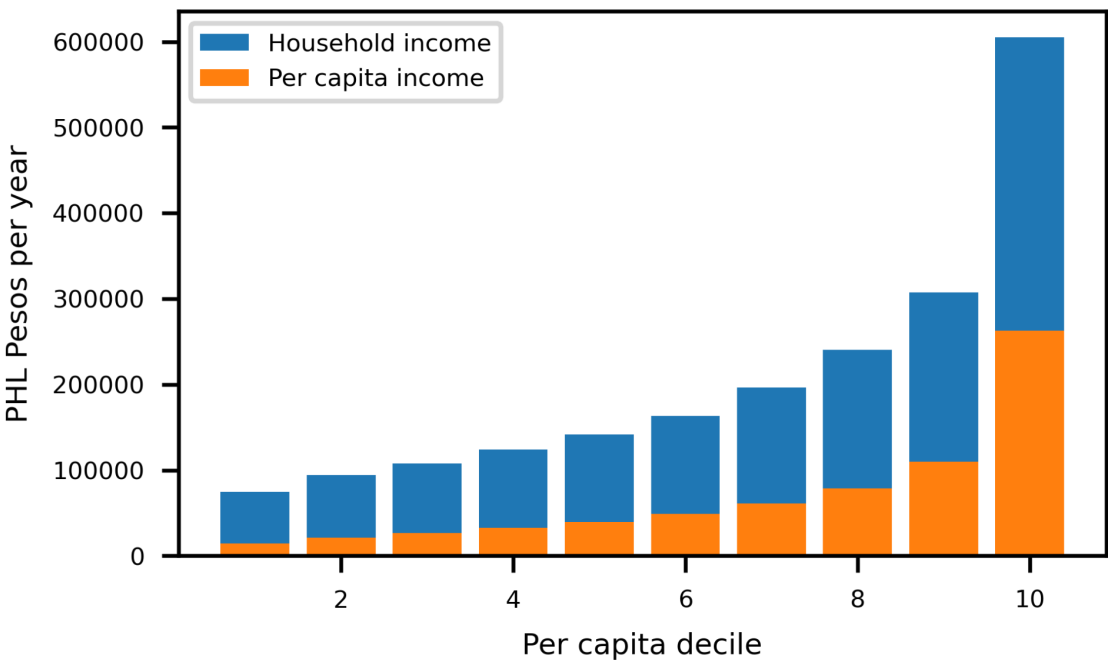
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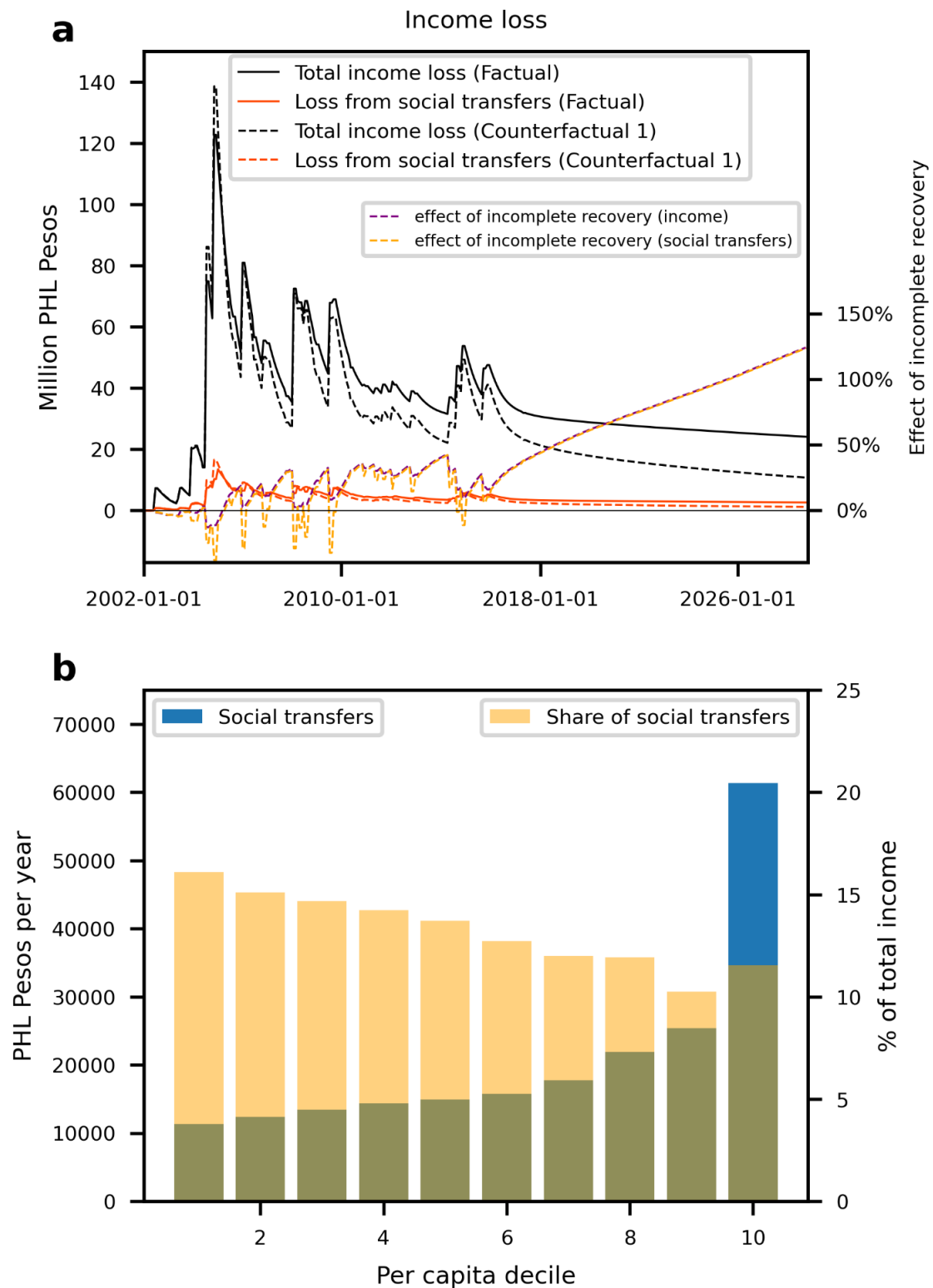
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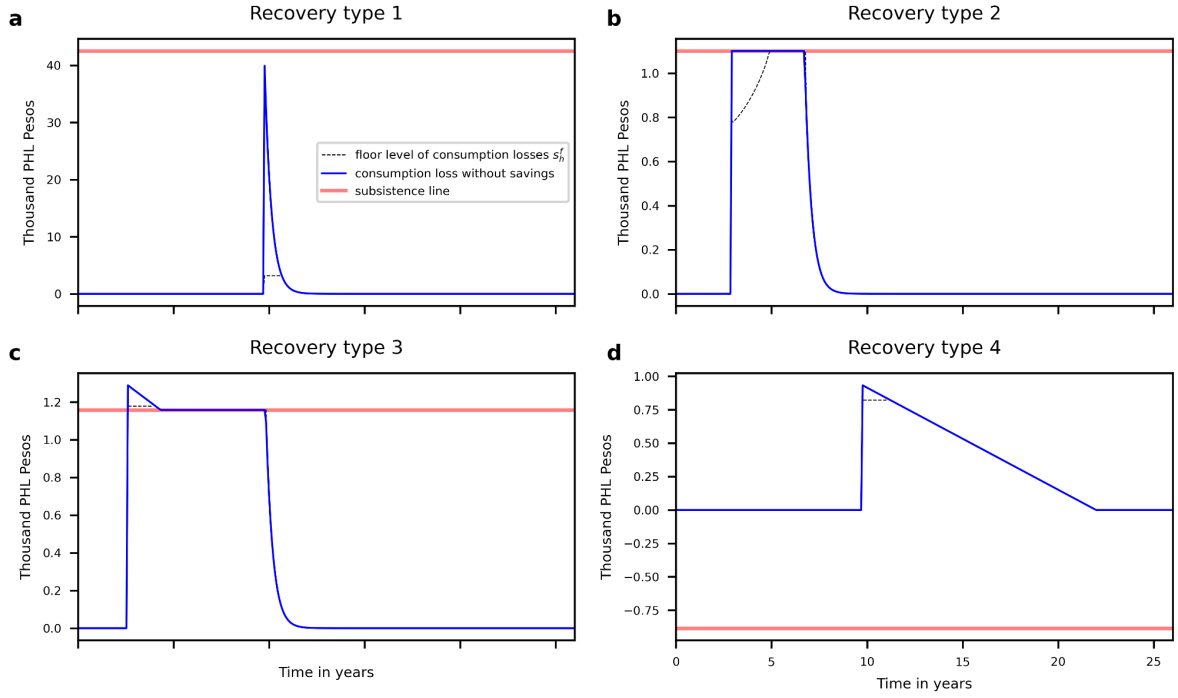
### Supplementary Figures



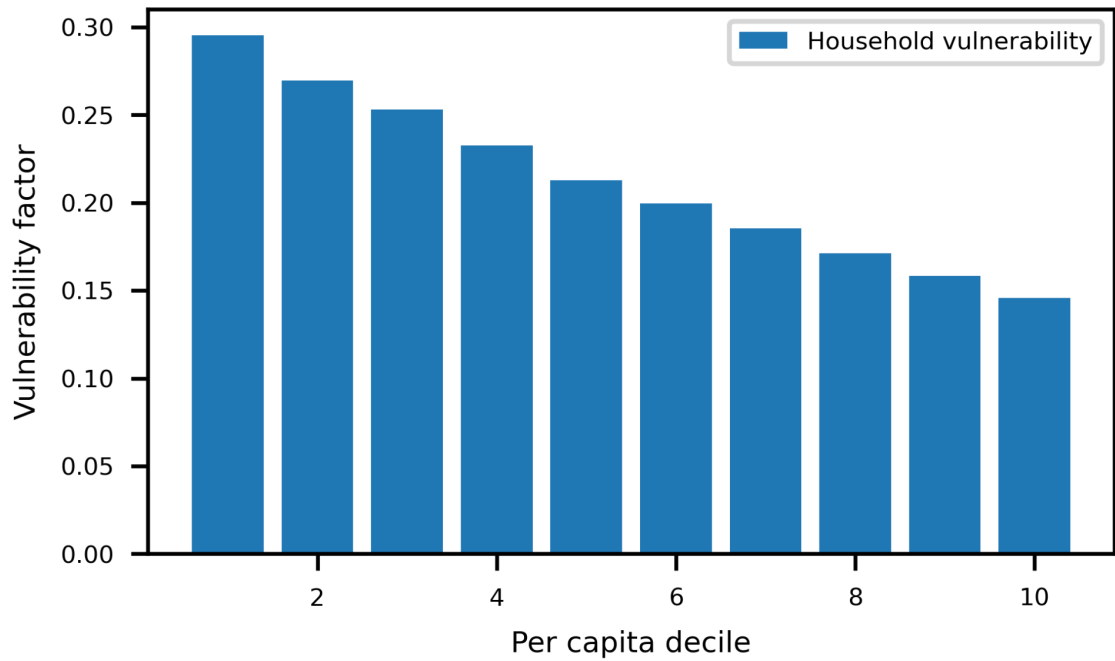
**Fig. S1: Income distribution across deciles.** Annual average household (blue) and per capita (orange) income across deciles as recorded in the Family Income and Expenditure Survey 2015 (FIES)(1).



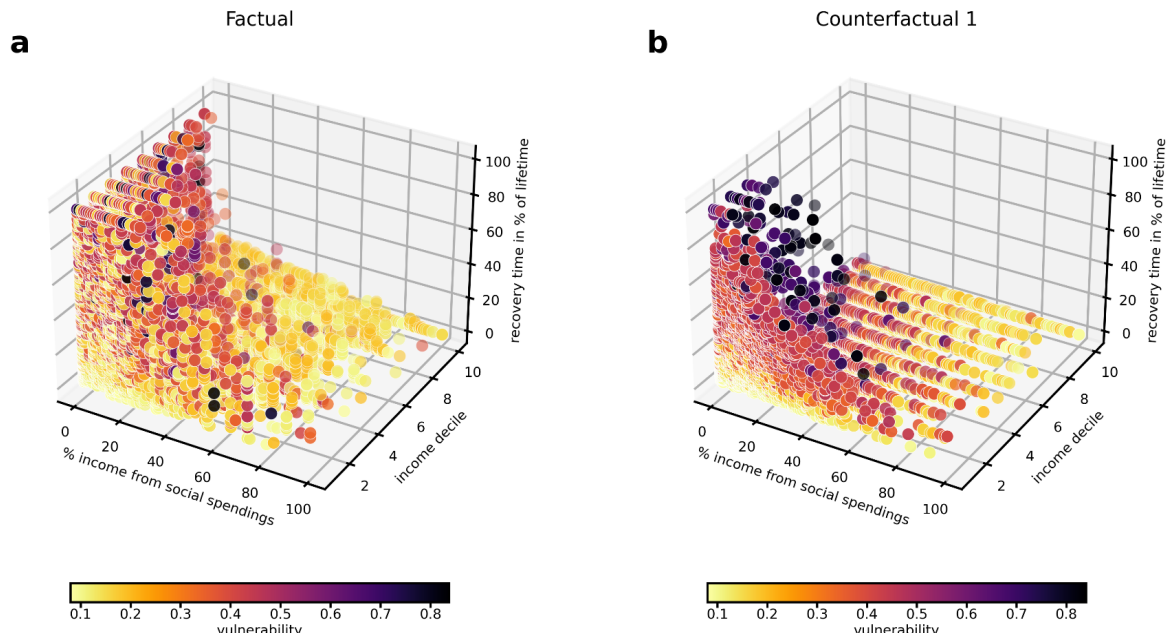
**Fig. S2: Income loss from social transfers.** **a** Total national income loss over time composed by income loss from lost assets and income loss due to reduced social transfers and the increase of income loss caused by incomplete recovery. **b** Average income from social transfers in absolute numbers of PHL Pesos (blue) and share of social transfers of total income in percent (orange).



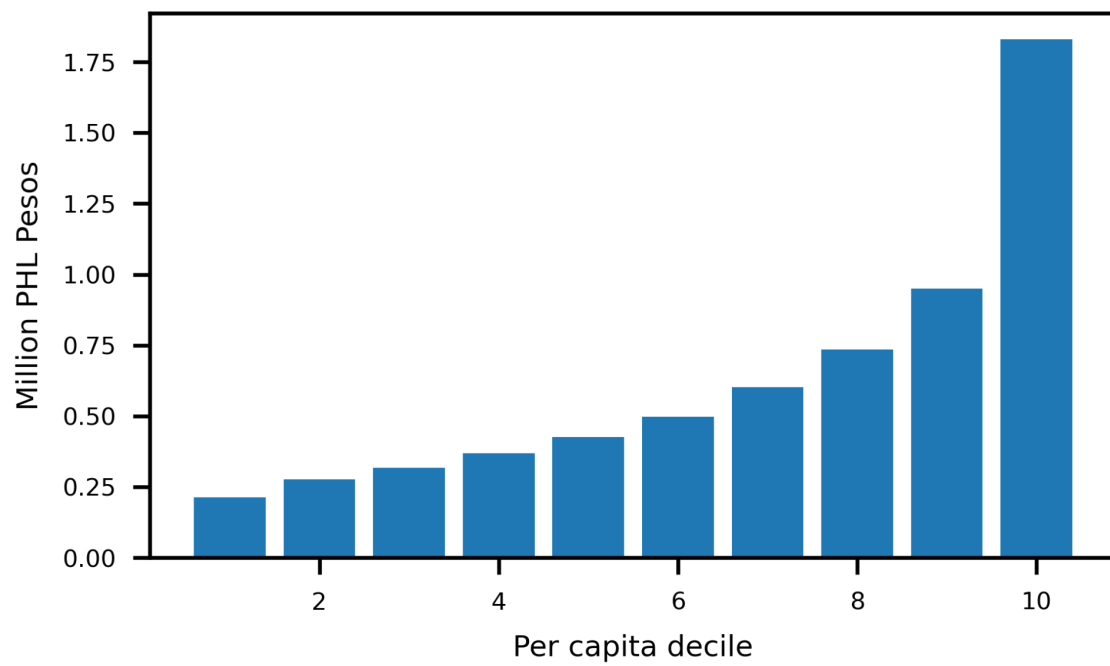
**Fig. S3: Recovery dynamics of consumption for different income levels. a Recovery type 1 - Recovery above subsistence line:** The household lives usually far above subsistence line (red line - consumption loss that can be compensated without falling under subsistence line), after a shock it can recover at an exponential rate  $\lambda_h^{t1}$  (well-being loss is minimized). The consumption loss is smoothed by the savings, the floor level of consumption losses  $s_h^{f,1}$  is determined directly after the shock. **b Recovery type 2 - Recovery along subsistence line:** The household lives usually above subsistence line (red line - consumption loss that can be compensated without living under subsistence line), after a shock it cannot recover at an exponential rate, as the household cannot afford the rate without crossing subsistence line. The household spends as much as possible without falling under subsistence line in each time step until exponential recovery is possible. The consumption loss is smoothed by the savings in each time step, with the expectation that the household recovers with the current constant recovery rate until recovery is completed  $s_h^{f,2}$  (black line). **c Recovery type 3 - Recovery starting under subsistence line:** The household lives usually above subsistence line (red line - consumption loss that can be compensated without living under subsistence line), but income is reduced through the shock, so that it lives under recovery line. It can only recover with the basic savings rate for people under subsistence line  $R_{sub}$  until it crosses the subsistence line, but can also lower its consumption losses to a floor level  $s_h^{f,3}$ . After crossing the subsistence line it recovers like a household of recovery type 2. **d Recovery type 4 - Recovery:** The household lives always under subsistence line (red line - consumption loss that can be compensated without living under subsistence line, in this case it is negative meaning that the household would need additional consumption to live above subsistence line). It can only recover with the basic savings rate  $R_{sub}$  for people under subsistence line over the entire recovery period. Savings are spent optimally to reduce peak consumption losses to the floor level  $s_h^{f,3}$ .



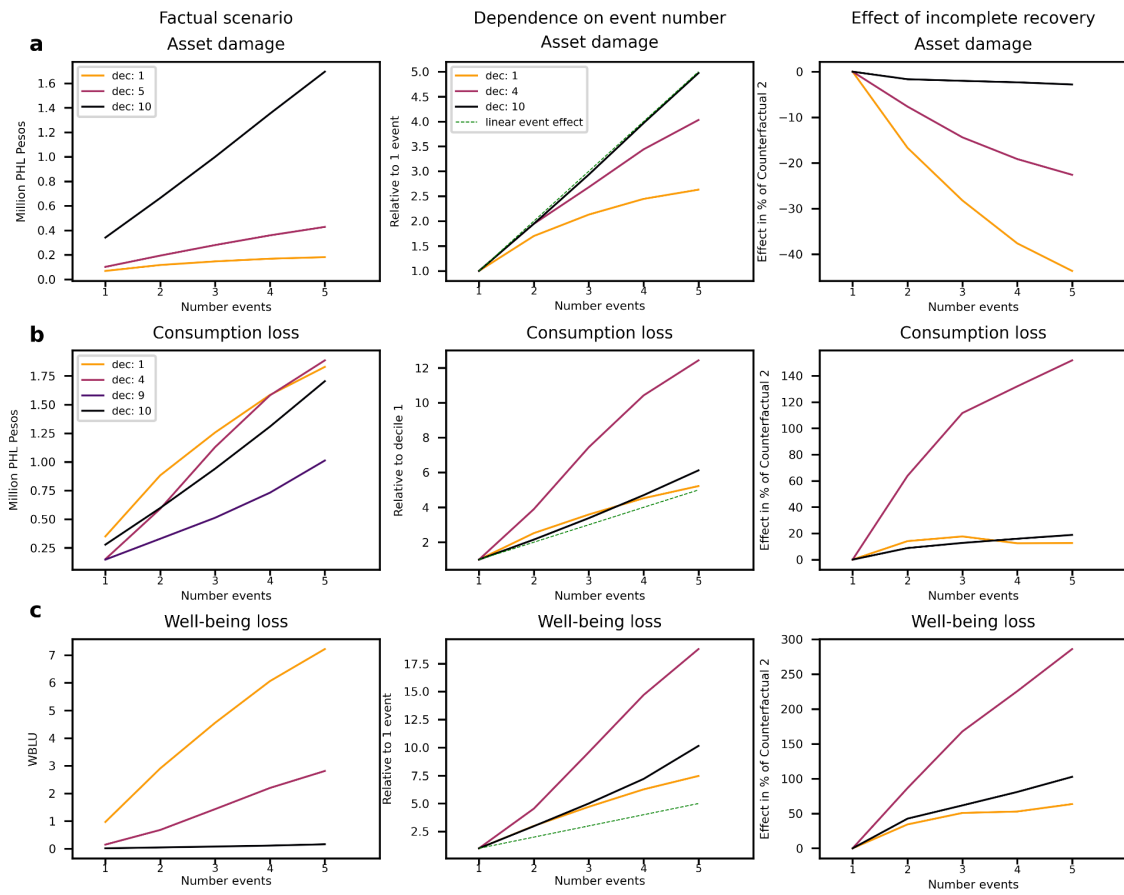
**Fig. S4: Income dependence of asset vulnerability.** Average asset vulnerability of each income group estimated from the building structure given in the FIES survey (cf. Tab. S1)(1).



**Fig. S5: Recovery time.** Recovery time of households plotted against income group and income share from social transfers for **a** the factual scenario and **b** counterfactual scenario 1. Colors indicate the household vulnerability factor.



**Fig. S6: Average assets per income group.** Average assets per household in million PHL Pesos estimated from income given in the FIES(1) and average productivity of capital stock  $\pi$ .



**Fig. S7: Distributional effects for households in dependence of the number of floods they experience.** **Left column:** Average damage to capital stock (**row a**), consumption loss (**row b**), and well-being loss (**row c**) for households from different income deciles that are affected by 1-5 flood shocks in the period 2002-2018 covered by the Global Flood Database(2) (factual scenario). **Middle column:** Average effect of additional events in each income decile that are affected by 1-5 flood shocks in the period 2002-2018. Damage and losses experienced under more than one event are normalized to the damage or loss experienced under only one event. **Right column:** Relative effect for households in each income decile that are affected by 1-5 flood shocks in the period 2002-2018. The effect of incomplete recovery is expressed as the ratio of the factual scenario and counterfactual scenario 2 assuming full recovery.

## Supplementary Tables

**Table S1: Household vulnerability estimated from the FIES.** The conversion of building structure to vulnerability factors was adopted from Walsh and Hallegatte 2020(3):

| <b>FIES descriptor</b>                                                              | <b>Category</b> | <b><math>v_h</math></b> |
|-------------------------------------------------------------------------------------|-----------------|-------------------------|
| Strong material(galvanized iron, brick, tile, concrete, aluminium, stone, asbestos) | robust          | $0.14 \pm 0.06$         |
| Mixed but predominantly strong materials                                            | robust          | $0.14 \pm 0.06$         |
| Light material (cogon, nipa, anahaw)                                                | moderate        | $0.40 \pm 0.08$         |
| Mixed but predominantly light material                                              | moderate        | $0.40 \pm 0.08$         |
| Savaged/makeshift materials                                                         | fragile         | $0.70 \pm 0.14$         |
| Mixed but predominantly salvaged materials                                          | fragile         | $0.70 \pm 0.14$         |
| Not Applicable                                                                      | fragile         | $0.70 \pm 0.14$         |

**Table S2:** Fraction of affected people for selection of affected households. The fraction of affected people for each event describes the ratio of exposed population (intersection of flooded area in the Global Flood Database(2) and population(4) and the number of affected people given in EMDAT(5).

| Event date | People GPW <sup>4</sup> ∩GFD <sup>2</sup> | Affected people <sup>5</sup> | $\frac{\text{Affected people}}{\text{GPW} \cap \text{GFD}}$ | Event date | People GPW <sup>4</sup> ∩GFD <sup>2</sup> | Affected people <sup>5</sup> | $\frac{\text{Affected people}}{\text{GPW} \cap \text{GFD}}$ |
|------------|-------------------------------------------|------------------------------|-------------------------------------------------------------|------------|-------------------------------------------|------------------------------|-------------------------------------------------------------|
| 2002-07-06 | 529648.073657                             | 25000                        | 0.047201                                                    | 2008-12-28 | 477420.923063                             | 3500                         | 0.007331                                                    |
| 2002-07-20 | 99391.152766                              | 7000                         | 0.070429                                                    | 2009-01-20 | 199822.089287                             | 0                            | 0.000000                                                    |
| 2003-06-25 | 80583.121466                              | 10000                        | 0.124095                                                    | 2009-02-02 | 228882.173275                             | 2000                         | 0.008738                                                    |
| 2003-07-19 | 89979.507447                              | 20000                        | 0.222273                                                    | 2009-07-25 | 183901.523160                             | 200000                       | 1.087539                                                    |
| 2003-12-19 | 159837.899234                             | 97500                        | 0.609993                                                    | 2009-10-02 | 454277.885026                             | 40000                        | 0.088052                                                    |
| 2004-02-11 | 220164.786894                             | 20000                        | 0.090841                                                    | 2010-05-29 | 168077.125278                             | 0                            | 0.000000                                                    |
| 2004-06-28 | 24287.928817                              | 1200                         | 0.049407                                                    | 2011-01-01 | 173781.808213                             | 10000                        | 0.057543                                                    |
| 2004-06-29 | 88684.885937                              | 0                            | 0.000000                                                    | 2011-02-01 | 60382.411675                              | 2000                         | 0.033122                                                    |
| 2004-07-31 | 303358.505541                             | 80000                        | 0.263714                                                    | 2011-06-05 | 308052.902209                             | 15000                        | 0.048693                                                    |
| 2004-08-24 | 346674.027814                             | 1058849                      | 3.054307                                                    | 2011-09-28 | 33044.842188                              | 180000                       | 5.447144                                                    |
| 2004-11-19 | 125839.330324                             | 35000                        | 0.278132                                                    | 2011-12-16 | 317968.544511                             | 1000                         | 0.003145                                                    |
| 2004-11-23 | 229550.519429                             | 8000                         | 0.034851                                                    | 2012-02-20 | 375595.484710                             | 25000                        | 0.066561                                                    |
| 2004-11-29 | 652651.266871                             | 432000                       | 0.661916                                                    | 2012-03-26 | 9213.469391                               | 0                            | 0.000000                                                    |
| 2005-07-27 | 168603.858063                             | 32782                        | 0.194432                                                    | 2012-12-04 | 31354.989244                              | 60000                        | 1.913571                                                    |
| 2005-09-15 | 197874.368509                             | 8000                         | 0.040430                                                    | 2013-01-04 | 107596.659291                             | 3180                         | 0.029555                                                    |
| 2006-01-26 | 253291.587455                             | 256641                       | 1.013224                                                    | 2014-06-17 | 270474.881883                             | 35000                        | 0.129402                                                    |
| 2006-07-11 | 3327.341003                               | 51680                        | 15.531922                                                   | 2014-09-19 | 357108.499699                             | 83000                        | 0.232422                                                    |
| 2006-11-30 | 121877.330934                             | 82915                        | 0.680315                                                    | 2014-12-10 | 249173.830060                             | 80186                        | 0.321807                                                    |
| 2007-01-10 | 209752.685031                             | 24508                        | 0.116842                                                    | 2015-10-22 | 473307.070817                             | 60000                        | 0.126768                                                    |
| 2007-10-27 | 43849.742729                              | 0                            | 0.000000                                                    | 2015-12-12 | 533209.287000                             | 20000                        | 0.037509                                                    |
| 2008-02-12 | 261197.833804                             | 873000                       | 3.342294                                                    | 2017-06-12 | 285080.604311                             | 0                            | 0.000000                                                    |
| 2008-05-10 | 234377.784121                             | 50000                        | 0.213331                                                    |            |                                           |                              |                                                             |
| 2008-07-28 | 119955.644804                             | 76000                        | 0.633568                                                    |            |                                           |                              |                                                             |

## References

1. Philippine Statistics Authority, Family Income and Expenditure Survey (FIES). *PSA* (2015) (May 26, 2020).
2. B. Tellman, *et al.*, Satellite imaging reveals increased proportion of population exposed to floods. *Nature* **596**, 80–86 (2021).
3. B. Walsh, S. Hallegatte, Measuring Natural Risks in the Philippines: Socioeconomic Resilience and Wellbeing Losses. *Economics of Disasters and Climate Change* **4**, 249–293 (2020).
4. E. Doxsey-Whitfield, *et al.*, Taking Advantage of the Improved Availability of Census Data: A First Look at the Gridded Population of the World, Version 4. *Papers in Applied Geography* **1**, 226–234 (2015).
5. EMDAT, EMDAT. *The OFDA/CRED international disaster database*, University Catholic Louvain-Brussels, Belgium. (2021) (May 26, 2021).